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THE MEMPHIS DEPOT
TENNESSEE

ADMINISTRATIVE RECORD
COVER SHEET

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AR# 812

EARLY IMPLEMENTATION OF SELECTED REMEDY

WORK PLAN

Defense Depot Memphis, Tennessee

Defense Logistics Agency

AFCEE Contract F41624-03-D-8606
Task Order No. 0069

MACTEC Engineering and Consulting, Inc.

Air Force Center for Environmental Excellence

November 2004, Rev. 1

812 2

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEFENSE LOGISTICS AGENCY
DEFENSE DISTRIBUTION CENTER
2001 MISSION DRIVE
NEW CUMBERLAND, PA 17070-5000

IN REPLY REFER TO DDC-DES-E

November 12, 2004

MEMORANDUM FOR: TURPIN BALLARD (USEPA-Region 4) and
JAMES MORRISON (TDEC)

SUBJECT: Early Implementation of Selected Remedy Work Plan, Rev. 1
MACTEC Engineering and Consulting, Inc.

The Early Implementation of Selected Remedy (EISR) Work Plan, Rev. 1 is attached. The work plan has been revised to reflect comments received by e-mail and personal communication through November 12, 2004.

For more information, please don't hesitate in contacting Thomas C. Holmes, Project Manager for MACTEC at (770) 421-3373.

MICHAEL A. DOBBS
Environmental Program Manager

Attachment on CD ROM:
Early Implementation of Selected Remedy Work Plan, Rev. 1
Distribution:
- EPA (3 copies)
- TDEC (3 copies)
- DDC (New Cumberland) (2 copies)
- AFCEE (1 copy)
- CH2M Hill (1 copy)
- Mitretek (1 copy)

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LIST OF ACRONYMS AND ABBREVIATIONS

AFCEE	Air Force Center for Environmental Excellence
BCT	BRAC Clean-up Team
BRAC	Base Realignment and Closure
CEHNC	U.S. Army Engineering and Support Center, Huntsville
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Chain of Custody
CVOC	Chlorinated Volatile Organic Compounds
DDMT	Defense Depot Memphis, Tennessee
DLA	Defense Logistics Agency
EISOPQAM	Environmental Investigations Standard Operating Procedures and Quality Assurance Manual
EISR	Early Implementation of Selected Remedy
EPA	U.S. Environmental Protection Agency
IDW	Investigative Derived Waste
MACTEC	MACTEC Engineering and Consulting, Inc.
MI	Main Installation
MLGW	Memphis Light Gas and Water
PCA	1,1,2,2-tetrachloroethane
PDB	Passive Diffusion Bag
PPE	Personal Protective Equipment
QA	Quality Assurance
QC	Quality Control
RACR	Remedial Action Completion Report
RASAP	Remedial Action Sampling and Analysis Plan
RD	Remedial Design
ROD	Record of Decision
TCE	Trichloroethene
TCLP	Toxicity Characteristic Leaching Procedure
TSDF	Transportation Storage or Disposal Facility
VOC	Volatile organic compound
ZVI	Zero-valent Iron

1.0 INTRODUCTION

MACTEC Engineering and Consulting, Inc. (MACTEC) has prepared this Early Implementation of Selected Remedy Work Plan for the Defense Depot Memphis, Tennessee (DDMT) under Contract F41624-03-D-8606, Task Order 0069, for the Air Force Center for Environmental Excellence (AFCEE) and the Defense Logistics Agency (DLA). The primary field activities include the installation of additional groundwater monitoring wells, groundwater sampling and analysis, and zero-valent iron (ZVI) injection using the Ferox^{SM} process.

Groundwater contaminant extent and selected remedies for groundwater were identified in the April 2004 Final Dunn Field Record of Decision (ROD). The remedy selected for treatment of groundwater for chlorinated volatile organic compounds (CVOCs) in the most contaminated part of the plume is injection of ZVI. ZVI consists of pure iron powder, which is specially manufactured and packaged to prevent premature corrosion. Once released into the environment, iron oxidation fosters anaerobic conditions, which yields ferrous iron and hydrogen ions, both of which are reducing agents for chlorinated solvents.

Based on the results of sampling conducted during the Remedial Design (RD) phase (June through October 2004), the DLA is conducting an Early Implementation of a Selected Remedy (EISR) using injection of ZVI to address the concentrations of CVOCs at the leading edge of the high concentration portion of the plume (within the 500 µg/L isopleth for total CVOCs). The selection of ZVI injection for this early remedy was partially based upon the results of a ZVI Treatability Study conducted from October 2003 to April 2004 as part of the RD for CVOC source areas on Dunn Field. The study was performed on Dunn Field in a known soil and groundwater contaminant source area centered around monitoring well MW-73. During this study, four injection points were installed in the study area along with five new monitoring wells and approximately 25,000 pounds of ZVI were injected into the fluvial aquifer. Over the course of five separate confirmatory sampling events, an 84 to 99 percent reduction of CVOCs was observed in the ZVI treatment zone. The treatability study was documented in a technical memorandum by CH2M Hill, Results of an *In-Situ Chemical Reduction Treatability Study using Zero-Valent Iron at Dunn Field, Memphis Depot, Tennessee,* Revision 0, September 9, 2004. On October 21, 2004, the Base Realignment and Closure (BRAC) Cleanup Team (BCT) approved a memorandum prepared by CH2M Hill, *Early Implementation of Selected Remedy Component to Address Groundwater Contamination West of Dunn Field,* Revision 1, dated October 14, 2004. This memorandum documents the basis for conducting the EISR, summarizes the site conditions and provides a general description of the remedy.

MACTEC has prepared this work plan to describe the activities and responsibilities required to perform the EISR (ZVI injection). ARS Technologies, Inc. (ARS), the selected ZVI contractor, has prepared a work plan for all activities to be performed by ARS and its subcontractors (**Appendix A**). The ARS FEROX^{sm} Field Injection Workplan was prepared while project planning was still in progress and has some conflicts with the MACTEC work plan. The MACTEC work plan will be the primary document and will govern activities during the EISR.

Monitoring well installation and groundwater sampling has already been performed as part of the EISR. The analytical results of the groundwater samples collected from the additional monitoring wells indicated that the 500 μg/L total CVOCs plume extends farther to the west-northwest than previously thought. Based on this additional information, and as discussed at the BCT meeting held the week of October 18, 2004, ZVI treatment will concentrate on the area designated Treatment Area 1 in the EISR TM. **Figure 1** shows the approximate locations of injection borings within Treatment Area 1. The work activities and analytical results for this groundwater sampling event will be included in the Early Implementation Remedial Action Completion Report.

The installation of the injection borings and monitoring wells, and sampling and analyses of groundwater will be performed as outlined in the Remedial Action Sampling and Analysis Plan (RASAP) (MACTEC, September 2004). The RASAP provides detailed procedures for field activities including drilling soil borings, well installation and sampling and analysis of groundwater samples.

1.1 SITE DESCRIPTION AND BACKGROUND

The Memphis Depot (formerly known as the Defense Distribution Depot Memphis, Tennessee and also referred to in this report as the DDMT) originated as a military facility in the early 1940s. The DDMT received, warehoused, and distributed supplies common to all U.S. military services and some civil agencies located primarily in the southeastern United States, Puerto Rico, and Panama. In 1995, the DDMT was placed on the list of the Department of Defense (DoD) facilities to be closed under BRAC. Storage and distribution of materiel for all U.S. military services and some civil agencies continued until the facility closed in September 1997.

The DDMT is in southeastern Memphis, Shelby County, Tennessee approximately 5 miles east of the Mississippi River and just northeast of Interstate 240. The property consists of approximately 642 acres and includes two components: the Main Installation (MI), which contains approximately 578 acres with open storage areas, warehouses, military family housing, and outdoor recreational areas, and Dunn Field, which contains approximately 64 acres and includes former mineral storage and waste disposal areas. Dunn Field is located across Dunn Avenue from the north-northwest portion of the MI. The lead agency for the site activities at the DDMT is the Defense Logistics Agency (DLA). The regulatory oversight agencies are the Environmental Protection Agency (EPA), Region 4 and the Tennessee Department of Environmental and Conservation (TDEC). The DDMT's EPA Identification Number is TN4210020570.

1.2 HYDROGEOLOGY

The four uppermost stratigraphic units underlying Dunn Field are (in descending order):

- Loess, including surface soil;
- Fluvial deposits;
- Jackson Formation/Upper Claiborne Group (the Jackson [if present], Cockfield, and Cook Mountain Formations); and
- Memphis Sand

Loess. The Quaternary-aged loess consists of wind-blown and deposited brown to reddish brown low-plasticity clayey silt (ML) or low plasticity silty clay (CL) and is continuous throughout the entire Dunn Field area. The loess deposits average about 20 to 30 feet thick.

Fluvial Deposits. The Quaternary- and possibly Pliocene-aged fluvial (terrace) deposits are composed of two generalized layers identified throughout the Dunn Field area. The upper layer is a silty, sandy clay that transitions to a clayey sand and ranges from about 10 feet to 36 feet thick. The lower layer is composed of layers of sand, sandy gravel, and gravelly sand, has an average thickness of approximately 40 feet at Dunn Field and along the eastern and western boundaries.

Jackson Formation/Upper Claiborne Group. The late Eocene-aged Jackson Formation/Upper Claiborne Group consists primarily of clays, silts and sands. The upper clay unit appears to be continuous underneath Dunn Field except at the southwestern boundary of Dunn Field. This clay unit is also absent to the west (MW-43) and northwest (MW-40) of Dunn Field. These windows in the clay provide connections for groundwater flow from the fluvial deposits to the underlying intermediate aquifer and eventually to the Memphis Sand. MW-40 is approximately 1,000 feet north of Treatment Area 1.

Memphis Sand. The Early to Middle Eocene-aged Memphis Sand is composed primarily of thick-bedded, white to brown or gray, very fine grained to gravely, partly argillaceous and micaceous sand. The Memphis Sand ranges from 500 to 890 feet thick and is at a depth of 120 to 300 feet bgs in the Memphis area. MW-67 is the only monitoring well completed in the Memphis Sand at the Memphis Depot; the top of the Memphis Sand was reached at a depth of 255 feet bgs (elevation of 21 feet msl).

There are three aquifers underlying Dunn Field which correspond to the geologic units described previously.

Fluvial Aquifer. The uppermost aquifer at Dunn Field is the unconfined fluvial aquifer, consisting of saturated sands and gravelly sands in the lower portion of the fluvial deposits. Recharge to this unit is primarily from the infiltration of rainfall, and discharge from the fluvial aquifer is generally directed toward underlying units in hydraulic communication with the fluvial deposits, or laterally into adjacent stream channels. Saturated thickness of the fluvial aquifer ranges between 3 and 30 feet at Dunn Field and to the west; the saturated thickness is controlled by the configuration of the uppermost clay in the Jackson Formation/Upper Claiborne Group. Water level elevations range from approximately 203 feet msl to 245 feet msl. Long-term groundwater elevation data for monitoring wells near Dunn Field indicate fluctuations in the water table of several feet in response to drought cycles. The potentiometric surface of the fluvial aquifer is shown on **Figure 2** and the top of uppermost clay is shown on **Figure 3**. Both figures also show the extent of the groundwater contaminant plume exceeding 100 micrograms per liter (µg/L).

Intermediate Aquifer. The intermediate aquifer underlying the Memphis Depot is locally developed in deposits of the Jackson Formation/Upper Claiborne Group, which also contain laterally extensive, thick deposits of clay. Away from areas of recharge from the fluvial aquifer, water level elevations in the intermediate aquifer range from approximately 161 feet msl to 189 feet msl, with a general westward flow.

Memphis Aquifer. The Memphis aquifer contains groundwater under strong artesian (confined) conditions and is a regionally significant source of potable water in the Memphis area. The Memphis aquifer is confined by overlying clays and silts in the Cook Mountain Formation (part of the

Jackson/Upper Claiborne Group). This aquifer receives most of its recharge from an outcrop area several miles east of Memphis. Some recharge is derived from overlying or hydraulically communicating units. Locally, extensive pumping has lowered water levels considerably. The top of the Memphis aquifer potentiometric surface at MW-67 is approximately 160 feet msl, while water levels in the fluvial aquifer are above 200 feet msl.

1.3 PURPOSE AND OBJECTIVES

The ZVI treatment is expected to reduce concentrations of 1,1,2,2-tetrachloroethane (PCA) and trichloroethene (TCE) in groundwater by 90% or greater based on results of the treatability study at Dunn Field. The early remedy implementation field effort will include three main activities to implement the EISR:

- Installation of additional monitoring wells
- Installation of ZVI injection points and injection of the ZVI into the fluvial aquifer
- Monitoring of groundwater prior to and subsequent to the injection

Since the installation and sampling of monitoring wells is a standard activity and the DLA directed that the EISR was to be performed on an expedited basis, the well installation and the majority of baseline sampling was completed prior to preparation of this work plan with concurrence from the BCT.

1.3.1 Additional Monitoring Well Installation

As shown in **Figure 1**, eight new monitoring wells (MW-158 and 158A through MW-164) were installed at seven locations up- and downgradient to the proposed early remedy implementation areas. One two-well cluster was installed in Area 1, approximately midway between existing wells MW152 and MW155. These wells are suitable for sampling using passive diffusion bag (PDB) samplers and have screen lengths of 15 feet. Two wells were sufficient to screen the full saturated thickness. The other locations have single wells with 20-foot screens installed above the uppermost clay.

1.3.2 ZVI Injection Points and Injection Locations

Based upon the results of the Dunn Field ZVI Treatability Study, the radius of influence of the ZVI injections was determined to be up to 40 feet, based upon the reduction of CVOC concentrations within monitoring well MW-131 located 40 feet from injection point IW-2. The mass of iron to be injected at each location is based upon a 0.5% iron to soil mass ratio within a 25-foot radius of injection (ROI) from each injection point. This injection distance is based upon observed presence of ZVI in confirmation borings during the treatability study.

Area 1

Fourteen points will be used for ZVI injection at Area 1 (**Figure 1**). The number of points proposed for this area is considered to provide sufficient overlap to treat groundwater flowing through the treatment zone. The Vertical Target Treatment Zone (VTTZ) for each injection boring within Area 1 will generally be the saturated thickness of the fluvial aquifer, which ranges between 10 to 28 feet in Area 1. However, the actual treatment zone thickness will be field determined and may vary based on the depth to the bottom of the targeted zone (top of the clay layer) and on observed stratification of contaminant concentrations in wells MW-155, MW-158, MW-158A and MW-159.

Area 2

The need to perform early implementation of ZVI injections in Treatment Area 2, located near well MW-144 and to the east-southeast of Treatment Area 1, will be determined at a later date.

1.3.3 Groundwater Monitoring

Groundwater samples will be collected from monitoring wells up- and down gradient of the treatment area(s) before and after injection of the ZVI to establish baseline groundwater chemistry and geochemical conditions and to confirm the reduction of the contaminants in groundwater. Samples will be collected through the use of passive diffusion bag (PDB) samplers and low-flow groundwater sampling techniques. The methods and procedures used in the field will adhere to procedures described in the RASAP.

Groundwater samples will be analyzed for VOC constituents as well as geochemical parameters, including the metals iron, magnesium, manganese, selenium, and arsenic, as well as calcium, alkalinity, nitrate, and nitrite.

The baseline samples will include groundwater samples collected from new and existing wells during multiple sampling events from August 2004 until ZVI injections begin in mid-November 2004. Baseline groundwater levels were measured in August and October 2004.

Two ground water monitoring events will be performed following the ZVI injection; samples will be collected from up to 25 monitoring wells in and around the injection zones one month and three months following the injections. Samples will be collected using low flow sampling techniques. Groundwater levels will be measured in approximately 50 wells during each of the two post-injection sampling events.

1.4 PROJECT ORGANIZATION AND RESPONSIBILITIES

Project organization and responsibilities for the field activities at the DDMT are discussed in the following subsections.

1.4.1 Project Organization

MACTEC will provide the project management and oversight services relating to ZVI injections, performance evaluation, data analysis and reporting. ARS and their subcontractors will perform the ZVI injection with integrated Rotasonic drilling.

1.4.2 Key Project Individuals

Key MACTEC participants in this project include the Program Manager, Project Manager/Principal, Task Manager, and Site Manager. The following paragraphs provide a description of the proposed project assignments and responsibilities, a list of individuals expected to serve in each capacity, and a brief synopsis of the participant's related experience.

The Program Manager is responsible for the administrative requirements and overall contractual agreements. Ms. Angela McMath is the Program Manger for DLA. Ms. McMath is a Principal Scientist with MACTEC, specializing in risk assessment. She is a Registered Hazardous Substances Professional with over 9 years experience in environmental consulting

Mr. Thomas Holmes is the Project Manager/Principal and is responsible for the overall management and quality of the project work. As Project Manager, he manages contractual and administrative requirements, manages schedules, and budgets for the program. As Project Principal, he is responsible for technical quality control and assurance, oversight and direction for all aspects of the project. The Project Manager also acts as the liaison between MACTEC and AFCEE. Mr. Holmes is a Registered Geologist in Georgia with over 25 years of environmental consulting experience.

Mr. David Price will serve as the MACTEC Task Manager for the ZVI injection program. Mr. Price is a registered Professional Geologist in Tennessee with over 18 years of experience in environmental consulting/remediation. Mr. Price will function as the primary point of contact for the site manager and is responsible for overall implementation of this work plan. Mr. Price will visit the site at selected phases of the project to ensure compliance with project documents and work plans. Mr. Price will review daily reports and weekly summary reports and will be responsible for preparing interim status reports and the Remedial Action Completion Report.

Mr. Kevin Arnold is a Project Geologist with MACTEC and will serve as the Site Manager for the EISR. Mr. Arnold's primary responsibilities include coordination for the implementation of this work plan and record keeping. Mr. Arnold will function as the primary point of contact for field operations and will be responsible for implementation of the Site Health and Safety Plan. All field activities will be coordinated and executed through the site manager. Mr. Arnold will work closely with the MACTEC Task Manager to ensure the successful completion of this project.

1.4.3 Subcontractors

Subcontractors for the EISR include the following:

- ARS Technologies, Inc. (ARS) – ZVI injection subcontractor (MACTEC subcontrator)
- Boart-Longyear - responsible for the injection borings (ARS drilling subcontractor)
- Prosonic, Inc. – drilling services for monitoring wells (MACTEC subcontractor)
- Allan & Hoshall, Inc. - surveying services (MACTEC subcontractor)
- All Points Logistics - industrial derived waste (IDW) transportation and disposal (MACTEC subcontractor)
- Severn Trent Laboratories (STL) – chemical analytical services (MACTEC subcontractor)

1.4.4 Drilling Services

Prosonic, Inc. located in Memphis, Tennessee will provide drilling services for monitoring well installation under subcontract to MACTEC. Prosonic will be responsible for providing and decontaminating the drill rig prior to and between each monitoring well location.

Injector borings will be performed by Boart-Longyear under subcontract to ARS. Installation and abandonment will be performed as outlined in the ARS Work Plan provided in **Appendix A**.

Decontamination procedures for drilling services will be conducted in accordance with Section 3.9 of the RA SAP.

1.4.5 Surveying Services

A Tennessee-licensed survey firm will be subcontracted to survey sample locations and elevations and provide the location data to MACTEC. The firm will report directly to the MACTEC Site Manager. Allen and Hoshall, is currently designated to provide surveying services for MACTEC at DDMT.

1.4.6 IDW Transportation and Disposal

All Points Logistics, Inc. will be subcontracted to transport and dispose of IDW generated during the EISR at the DDMT. The firm will report directly to the MACTEC Site Manager during field activities.

1.4.7 Chemistry Laboratory Services

Severn Trent Laboratories (STL), North Canton, Ohio will be subcontracted to perform analysis for the groundwater samples collected during the EISR. STL will be responsible for providing sample shipping containers, chain-of-custody documents, chemical analysis and reporting, and laboratory quality assurance (QA)/quality control (QC).

2.0 FIELD ACTIVITIES

This section describes the field activities that will be performed as part of the EISR at Dunn Field. The field activities schedule is shown on **Table 1**.

2.1 MONITORING WELL INSTALLATION AND BASELINE SAMPLING

Additional monitoring wells were installed to confirm the area to be addressed by the interim remedial action and to allow post-injection monitoring. Based on discussions at the August BCT meeting, eight groundwater monitoring wells were installed at seven locations. The wells were installed in borings drilled by rotasonic techniques in the same manner as recently installed wells in the area. Soil samples were collected from the capillary fringe and the saturated interval for analysis of VOCs, iron and total organic carbon. Wells were developed by surging. Well installation and sampling were performed in accordance with the RASAP. During groundwater sampling, field parameters (pH, temperature specific conductivity, temperature, turbidity, dissolved oxygen and oxygen reduction potential) were measured. Soil and water investigation derived waste will be tested and disposed properly.

Groundwater samples were collected from the eight new wells following installation using low flow and PDB sampling techniques. Multiple samples are being collected from the cluster well and from wells (MW-155 and MW-159) to address questions of contaminant stratification. The analytical results for the groundwater samples from the wells installed in October and for samples collected in new and existing wells west of Dunn Field in August are included on **Table 2**. The initial groundwater samples were collected using low flow sampling following well installation and development. PDBs were placed at 5-foot intervals in the saturated screened intervals of wells MW-158 and MW-158A on October 14, 2004 and in MW-155 and MW-159 on October 22, 2004. The PDBs were retrieved on November 8, 2004.

2.2 ZVI INJECTION

ZVI injections are planned at 14 locations in borings advanced using rotasonic drilling. The borings will be spaced to provide as complete coverage of the treatment areas as possible given access constraints. The planned injection locations are shown on **Figure 1**. The treatability study has been reported by CH2M Hill to indicate a radius for ZVI injection of at least 25 feet and a radius of influence of up to 40 feet from the injection location. ZVI injections will be made at successive 2-foot vertical intervals to effectively treat the full saturated thickness of the fluvial aquifer at each injection location. If results of

PDB samples confirm the stratification of VOCs in the aquifer as indicated by the initial samples from wells MW-158 and MW-158A, ZVI injection intervals may be revised to target the aquifer intervals with the highest VOC concentrations. A total of 280 feet of vertical treatment (140 2-foot injection intervals) is planned for the EISR.

2.2.1 Site Reconnaissance and Preparation

Prior to field operations, the MACTEC Site Manager will conduct a site reconnaissance to determine requirements for site preparation and clearance. Site preparation will include limited site improvement by clearing brush or other obstructions. Proposed injection boring locations will be clearly staked and marked by the surveyor. The locations will be cleared for underground utilities in the area. The height of overhead transmission lines will be measured from ground surface to confirm clearance for drilling. A twenty-foot separation distance from the transmission lines to the top of the drilling mast will be considered sufficient clearance. An onsite meeting was held between Jason Mayo of MLGW and the Site Manager on October 3, 2004. Overhead utilities, proper clearance and the need to have a representative from MLGW onsite during drilling and injection operations were discussed. Also on October 3, 2004, area clearance for utilities was conducted by Heath Consultants and UPS locators through Tennessee One Call. No intrusive activities will be conducted until clearance for utilities has been completed.

The MACTEC Site Manager and Task Manager met with ARS on November 3-4, 2004. The agenda prepared for this meeting is included as **Appendix B**. The major topics covered at this meeting include project planning, design and coordination, submittal status, site work planning, quality control, review of the Health and Safety Plan, site inspection, and general discussion items. ARS will provide documentation of the purity of the ZVI prior to delivery at DDMT and will also provide samples from the batches of ZVI to be delivered for analysis. The samples will be submitted to Severn Trent Laboratories for metals analysis by EPA Method 6010B.

2.2.2 Mobilization and Site Preparation

MACTEC will oversee mobilization of contractor equipment and personnel, currently scheduled to begin on November 15, 2004. If changes are made during the meeting with ARS, injection locations will be re-surveyed and an additional utility clearance performed. MACTEC will coordinate with MLGW to assure a representative is onsite if required. Work zones will be established and a decontamination pad will be constructed if necessary.

A Notice of Remedial Action Implementation will be submitted to EPA upon mobilization of contractors to the site.

2.2.3 ZVI Injections

Any changes in material, equipment and procedures between this action and the 2003 Dunn Field treatability study will be identified by ARS and approved by the MACTEC project manager prior to implementation.

The ZVI powder will be transported to DDMT and stored under cover at a warehouse at the Memphis Depot in 2,000-pound super sacks. ZVI will be taken from the warehouse to Area 1 in the super sacks and then transferred to the hopper. The hopper will be equipped with an auger-type conveyance system that will add the ZVI to a batch mixing tank until the mass of iron meets the predetermined water/ZVI mass ratio. ZVI transfer will be performed in a manner to minimize any airborne release of ZVI. Particulate monitoring will be performed as described in Section 2.4.

The ZVI mixture will then be injected in borings advanced using rotasonic drilling. Injections for each boring will begin by injecting a two-foot interval at the bottom-most interval of each boring, typically the top of clay at the base of the fluvial aquifer. A packer will be used at the top of each two-foot section to force the injectate into the surrounding formation. The goal of the injection process is to place 1,350 to 1,400 pounds of ZVI evenly distributed within each 2-foot injection interval and the 25-foot radius of injection. After the injection process has been completed for a given two-foot section, the packer will be depressurized and the packer and injection tool will be raised for the next two-foot interval. This injection process will continue to the top of the treatment zone, typically the estimated water table or capillary fringe.

The planned locations of the Area 1 injection locations are provided in **Figure 1**. The injection borings have been positioned to provide sufficient coverage of the treatment area given access constraints. The treatability study has been reported by CH2M Hill to indicate a radius for ZVI injection of at least 25 feet and a radius of influence of up to 40 feet from the injection location. In general, ZVI injections will be made at successive 2-foot vertical intervals to effectively treat the full saturated thickness of the fluvial aquifer at each injection location. The aquifer thickness varies from 10 feet to 28 feet in Treatment Area 1. Surface elevations will be surveyed prior to the injections and recent groundwater level measurements will be used to determine the depth of the upper limit for injection at each location. **Table 3** provides a listing of injection locations with the target saturated thicknesses (vertical treatment interval) based on top of clay and water table elevations. Logs for the monitoring well borings drilled in Area 1 are included in **Appendix C**. As stated previously, the treatment intervals may be revised upon receipt of PDB sample results.

ARS has estimated that up to 189,000 pounds of H-200 zero-valent sponge iron will be required to achieve the treatment objectives for Area 1. The mass of iron injected has been calculated by ARS to create a 0.5% iron to soil mass ratio to achieve the goal of 90% reduction of TCE and PCA in groundwater, assuming even distribution over a 25-foot radius of injection and a 2-foot vertical injection interval. This ratio is derived from ARS' experience and represents the optimal target ZVI dosage; the dosage is greater than that achieved during the 2003 ISCR treatability study. The mass of ZVI was estimated from preliminary data due to the lead time required for production and for shipment to DDMT. The mass of ZVI ordered is based on a total of 140 injection intervals, which is considered sufficient for this EISR.

Other injection parameters, the injection system set up and injection procedures will be the same as in the treatability study. ARS' Work Plan is provided in **Appendix A**. The depth of each injection, the amount of iron injected and the injection parameters will be recorded at each location. Injection parameters will include nitrogen gas pressure and flow rate during the initial pneumatic fracturing/fluidization phase and injection pressure and flow rate of the ZVI/water mixture during the injection phase. Gas pressure in monitoring wells near the injection points will be recorded using "drag arm" pressure gauges, which record peak pressure. In addition, water levels will be measured in nearby monitoring wells during the injection process.

2.2.4 Demobilization and Site Restoration

Upon completion of the injections, all borings will be grouted to the surface using a tremie pipe. The portion of the boring in the fluvial deposits is expected to collapse following injections; grout will be placed in the section within the loess deposits which extend to a depth of approximately 30 feet; this is considered to provide an effective surface seal. The injection and well installation sites will be returned to the condition existing prior to the interim remedial action to the extent feasible. Gravel placed to improve site access will be removed where necessary. A post-construction inspection, including meeting with MLGW personnel and other property owners, will be performed to confirm that restoration requirements have been met. Field notes related to the pre-ZVI injection meeting, field notes documenting the actual ZVI injection, field notes associated with each groundwater sampling event and associated analytical will be placed in the project file.

2.3 POST INJECTION MONITORING

Two ground water monitoring events will be performed following the ZVI injection; samples will be collected from approximately 25 monitoring wells in and around the injection zones one month and three months following the injections. Samples will be collected using low flow sampling techniques. Field parameters, including dissolved oxygen and oxygen reduction potential, will be measured during sampling. Groundwater levels will be measured in approximately 50 wells during each of the sampling events. The wells included in the baseline water level measurements and to be used for post-injection measurements are listed on **Table 4**. The monitoring wells included in baseline groundwater sampling and those planned for post-injection monitoring are listed on **Table 5**. The field and laboratory analytical parameters for baseline and post-injection monitoring are shown on **Table 6**.

2.4 HEALTH AND SAFETY

A Site Health and Safety Plan (HASP) was prepared by MACTEC in April 2004 to provide guidance for field activities at DDMT. An addendum to that HASP has been prepared for the EISR to address activities associated with the injection (**Appendix D**). Prior to the commencement of the field activities, all MACTEC employees will be required to read the HASP and HASP Addendum and sign the HASP Acknowledgement Form. Health and safety issues will be discussed on a daily basis.

MACTEC will conduct monitoring to determine if particulate concentrations are elevated during ZVI mixing and other activities with increased potential for airborne release of ZVI. The physical characteristics of the ZVI, especially density of 2.4 to 2.5 grams per cubic centimeter, indicate that it will not become suspended in air. Particulate monitoring will be performed using a portable monitor (ThermoMIE Model PDR-1000 AN) at the work zone and at an upwind and a downwind location on an hourly basis during ZVI handling. Monitoring will be discontinued if measurements consistently show particulate concentrations are negligibly different between upwind and downwind locations.

ARS will also prepare a Health and Safety Plan to be followed by its employees and subcontractors, and will provide a copy of the plan to MACTEC. MACTEC will provide ARS a copy of the Site Health and Safety Plan and the addendum prepared for this action for information.

2.5 MANAGEMENT OF INVESTIGATION DERIVED WASTE

IDW generated during this investigation will consist of soil cuttings from borings, construction debris (primarily pallets and spent super sacks), PPE and waste water generated during the Ferox^{SM} injections. Waste may be classified as non-investigative waste or investigative/field-generated waste. Non-investigative waste, such as litter and construction debris, will be collected on an as-needed basis to maintain the site in a clean and orderly manner. This waste will be containerized for transport to the designated sanitary landfill or collection bin. Acceptable containers will be sealed containers or plastic garbage bags.

Investigative/field-generated waste will be properly containerized and temporarily stored at the site prior to offsite disposal. The number of containers will be estimated on an as needed basis. Acceptable containers will be sealed, U.S. Department of Transportation approved steel 55-gallon drums or roll-off box-type containers. The containers will be transported in a manner to prevent spillage or particulate loss to the atmosphere.

The field-generated waste will be segregated at the site according to the matrix (solid, including soil, sediment, and PPE, or liquid, such as waste water) and means of derivation (drill cuttings and decontamination fluids). Each container will be properly labeled with site identification, sampling point, depth, matrix, COC, and other pertinent information for handling.

Soil cuttings generated from injection well installation procedures will be placed in drums or other appropriate storage devices and stored at the site. The soil will be sampled for final disposal purposes according to methods and analyses required by the accepting CERCLA approved transportation/storage/disposal facility (TSDF). After the soil analytical data have been obtained, the soil will be removed from the Dunn Field within 60 days.

Waste water from well sampling, well development, and equipment decontamination will be transported from the well, using either drilling rig support trucks or sealed containers, to a fractionation tank at Dunn Field. At the completion of activities the waste water will be sampled. If the concentrations are below those listed in the City of Memphis Industrial Wastewater Discharge under Permit No. S-NN3-097, water will be discharged via the Dunn Field treatment system. If the concentration limits are not met, a waste water treatment and disposal plan will be developed.

Soil from borings and material from well abandonment is placed into roll-off boxes. The boxes will be sampled and analyzed for TCLP VOCs for final disposal purposes. If the results are less than the TCLP regulatory levels, the soil will be disposed of as non-hazardous Investigative Derived Waste at a landfill approved to accept CERCLA off-site waste. If the results exceed TCLP regulatory levels, the material will be disposed of in accordance with appropriate hazardous waste disposal requirements.

3.0 REPORTING

An EISR remedial action completion report (EISR RACR) will be prepared to document the ZVI installation including final injection locations, quantity of ZVI injected and results of initial monitoring. The RACR will include a chronology of events, performance standards and cleanup standards achieved, description of the QA/QC procedures followed and documentation of the final inspection.

Additional technical memoranda will be prepared upon receipt of groundwater analytical results from post injection monitoring. The reports will present the analytical results and groundwater flow data and will compare the data to previous results.

A final report will be prepared upon completion of all sampling and data validation. The report will provide a detailed review of the interim remedial action and its short-term effectiveness.

4.0 REFERENCES

CH2M Hill, 2004a. Results of In Situ Reduction Treatability Study using Zero-Valent Iron at Dunn Field, Memphis Depot, Tennessee. Prepared for the U.S. Army Engineering and Support Center, Huntsville. September, 2004.

CH2M Hill, 2004b. Early Implementation of Selected Remedy Component to Address Groundwater Contamination West of Dunn Field. Prepared for the U.S. Army Engineering and Support Center, Huntsville. October, 2004.

MACTEC, 2004. Remedial Action Sampling and Analysis Plan, Defense Depot Memphis, Tennessee, Rev.0. Prepared for the Air Force Center for Environmental Excellence. September, 2004.

TABLES

TABLE 1

Early Implementation of Selected Remedy
Defense Depot Memphis, Tennessee

Field Work Schedule

Task ID	Task Name	Duration (Days)	Start	Finish
1	Survey Monitoring Well locations	1	Wed 9/29/04	Wed 9/29/04
2	Utility Clearance for Monitoring Wells	1	Thu 9/30/04	Thu 9/30/04
3	Monitoring Well Installation	10	Mon 10/4/04	Wed 10/13/04
4	Baseline Groundwater Sampling	9	Thu 10/7/04	Fri 10/15/04
5	Survey Injection Well Locations	1	Tue 11/2/04	Tue 11/2/04
6	Utility Clearance for Injection Wells	2	Tue 11/2/04	Wed 11/3/04
7	Premobilization Meeting with ARS	2	Wed 11/3/04	Thu 11/4/04
8	Mobilization for ZVI Treatment	3	Mon 11/15/04	Wed 11/17/04
9	ZVI Treatment - Shift One	7	Thu 11/18/04	Wed 11/24/04
10	ZVI Treatment - Shift Two	10	Mon 11/28/04	Wed 12/8/04
11	ZVI Treatment - Shift Three	10	Mon 12/13/04	Wed 12/22/04
12	ZVI Treatment - Shift Four	4	Mon 12/27/04	Thu 12/30/04
13	Demobilize for ZVI Treatment	3	Wed 1/5/05	Fri 1/7/05
14	Additional Monitoring Well Installation	10	Mon 11/8/04	Wed 11/17/04
15	Groundwater Sampling	12	Mon 11/8/04	Fri 11/19/04
16	Post ZVI Injection Sampling - Event One	10	January	January
17	Post ZVI Injection Sampling - Event Two	10	March	March

TABLE 2

SUMMARY OF VOLATILE ORGANIC COMPOUNDS IN GROUNDWATER SAMPLES
DDMT, Dunn Field
August and October 2004

Constituents	Well Number	MW-31	MW-32	MW-44	MW-54	MW-70	MW-76	MW-77	MW-79
	Sample ID	MW-31	MW-32	MW-44	MW-54	MW-70	MW-76	MW-77	MW-79
	Approximate Sample Depth (ft. bgs)	76.5	66.4	70.9*	93.0	89.6	92.8	87.7	101.3
	Date Sampled	8/12/2004	8/13/2004	8/14/2004	8/14/2004	8/14/2004	8/16/2004	8/15/2004	8/13/2004
Volatile Organic Compounds-SW846 8260B (µg/L)									
Acetone		2.5 J	5.1 J	**25**	340 J	200 J	<10	<1700	0.84 J
Benzene		<1.7	0.61 J	<1.0	<100	<120	<2.0	<330	<1.0
Bromodichloromethane		<1.7	<2.5	<1.0	<100	<120	<2.0	<330	<1.0
Bromoform		<1.7	<2.5	<1.0	<100	<120	<2.0	<330	<1.0
2-Butanone (MEK)		<8.4	<12	<5.0	<500	<620	<10	<1700	<5.0
Carbon Disulfide		<1.7	<2.5	<1.0	<100	<120	<2.0	<330	<1.0
Carbon tetrachloride		<1.7	**7.6**	0.8 J	<100	<120	<2.0	<330	0.77 J
Chlorobenzene		<1.7	<2.5	<1.0	<100	<120	<2.0	<330	<1.0
Chloroform		<1.7	**68**	0.4 J	<100	<120	0.47 J	<330	<1.0
Chloromethane		<1.7	<2.5	<1.0	<100	<120	<2.0	<330	<1.0
1,1-Dichloroethane		<1.7	<2.5	<1.0	<100	<120	<2.0	<330	<1.0
1,2-Dichloroethane		<1.7	<2.5	<1.0	<100	<120	<2.0	<330	<1.0
cis-1,2-Dichloroethene		<1.7	**2.8**	<1.0	65 J	<120	**6.9**	94 J	**1.9**
trans-1,2-Dichloroethene		<1.7	<2.5	<1.0	<100	<120	**3.5**	<330	**1.6**
1,1-Dichloroethene		**26**	<2.5	<1.0	<100	<120	<2.0	<330	**7.6**
Methylene chloride		<1.7	2.1 J	<1.0	<100	<120	<2.0	<330	<1.0
Methyl tert-butyl ether (MTBE)		<8.4	<12	<5.0	<500	<620	<10	<1700	<5.0
1,1,2,2-Tetrachloroethane		<1.7	**21**	<1.0	**2300**	**3500**	**2.9**	**11000**	<1.0
Tetrachloroethene		0.59 J	0.97 J	<1.0	<100	<120	1.8 J	<330	**1.7**
Toluene		<1.7	<2.5	<1.0	<100	<120	<2.0	<330	<1.0
1,1,1-Trichloroethane		0.36 J	<2.5	<1.0	<100	<120	<2.0	<330	0.27 J
1,1,2-Trichloroethane		<1.7	<2.5	<1.0	<100	<120	<2.0	<330	<1.0
Trichloroethene		**5.5**	**24**	0.28 J	**2200**	**970**	**34**	**3200**	**14**

J = estimated result. Result less than reporting limit
BGS = below ground surface
* = Sample depth at MW-44 based on total depth measurement
of 72.89' below top of casing on 8/17/04

TABLE 2

SUMMARY OF VOLATILE ORGANIC COMPOUNDS IN GROUNDWATER SAMPLES
DDMT, Dunn Field
August and October 2004

Constituents	Well Number	MW-80	MW-144	MW-144	MW-145	MW-147	MW-148	MW-149	MW-150	MW-151
	Sample ID	MW-80	DUNNDUP-1	MW-144	MW-145	MW-147	MW-148	MW-149	MW-150	MW-151
	Approximate Sample Depth (ft. bgs)	72.2	74.8	74.8	95.2	76.1	86.5	98.7	90 4	95.1
	Date Sampled	8/17/2004	8/12/2004	8/12/2004	8/16/2004	8/17/2004	8/17/2004	8/18/2004	8/18/2004	8/16/2004
Volatile Organic Compounds-SW846 8260B (µg/L)										
Acetone		0.94 J	840 J	690 J	**20**	6.0 J	0.93 J	**61**	<1200	**10**
Benzene		0.23 J	<250	<250	<1.0	1.2 J	<1.0	<5.0	<250	<1.0
Bromodichloromethane		<1 0	<250	<250	<1.0	<5.6	<1.0	<5.0	<250	<1.0
Bromoform		<1.0	<250	<250	<1.0	<5.6	<1.0	<5.0	<250	<1.0
2-Butanone (MEK)		<5.0	<1200	<1200	<5.0	<28	<5.0	<25	<1200	<5.0
Carbon Disulfide		<1.0	<250	<250	<1.0	<5.6	<1.0	<5.0	<250	<1.0
Carbon tetrachloride		<1.0	<250	<250	<1.0	4 3 J	0.73 J	**12**	<250	**2.7**
Chlorobenzene		<1.0	<250	<250	<1.0	<5.6	<1 0	<5.0	<250	<1.0
Chloroform		<1.0	<250	<250	<1.0	**12**	0.60 J	**110**	<250	**3.3**
Chloromethane		<1.0	<250	<250	<1.0	<5.6	<1.0	<5.0	<250	0.21 J
1,1-Dichloroethane		<1 0	<250	<250	<1.0	<5.6	<1.0	<5.0	<250	<1.0
1,2-Dichloroethane		<1.0	<250	<250	<1.0	<5.6	<1.0	<5.0	<250	<1.0
cis-1,2-Dichloroethene		<1.0	73 J	68 J	<1.0	**57**	**13**	3.8 J	74 J	0.22 J
trans-1,2-Dichloroethene		<1 0	<250	<250	<1 0	**20**	**4.9**	<5.0	<250	<1.0
1,1-Dichloroethene		<1 0	<250	<250	<1.0	2.2 J	<1.0	<5 0	<250	<1.0
Methylene chloride		<1.0	<250	<250	<1.0	<5.6	<1.0	2.5 J	130 J	<1.0
Methyl tert-butyl ether (MTBE)		<5.0	<1200	<1200	<5.0	<28	<5.0	<25	<1200	<5.0
1,1,2,2-Tetrachloroethane		<1.0	**7700**	**7700**	<1.0	**56**	0.72 J	**27**	**8000**	<1.0
Tetrachloroethene		<1.0	<250	<250	<1.0	5.3 J	**3.7**	1 6 J	<250	<1.0
Toluene		<1.0	<250	<250	<1.0	<5 6	<1.0	<5.0	<250	**1.1**
1,1,1-Trichloroethane		<1.0	<250	<250	<1.0	<5.6	<1.0	<5.0	<250	<1.0
1,1,2-Trichloroethane		<1.0	<250	<250	<1.0	<5.6	<1.0	<5.0	<250	<1.0
Trichloroethene		<1.0	**2800**	**2800**	<1.0	**120**	**31**	**38**	**3000**	**2.2**

J = estimated result. Result less than reporting limit
BGS = below ground surface
* = Sample depth at MW-44 based on total depth measurement
of 72.89' below top of casing on 8/17/04

TABLE 2

SUMMARY OF VOLATILE ORGANIC COMPOUNDS IN GROUNDWATER SAMPLES
DDMT, Dunn Field
August and October 2004

Constituents	Well Number	MW-152	MW-152	MW-152	MW-152	MW-152	MW-153	MW-154	MW-155
	Sample ID	MW-152	MW-152, 10 ft	MW-152, 2.5 ft	MW-152, 2.5 ft	MW-152, 10 ft	MW-153	MW-154	MW-155
	Approximate Sample Depth (ft. bgs)	107.4	106	98.5	91.3	98.8	94 1	65.8	93.7
	Date Sampled	8/15/2004	10/10/2004	10/11/2004	10/14/2004	10/14/2004	8/19/2004	8/17/2004	8/16/2004
Volatile Organic Compounds-SW846 8260B (µg/L)									
Acetone		6.1 J	<25	<25	<25	NA	0.92 J	1.7 J	<380
Benzene		<3.3	<5.0	<5.0	<5.0	NA	<1.0	0.38 J	<77
Bromodichloromethane		<3.3	<5.0	<5.0	<5.0	NA	<1.0	<1.0	<77
Bromoform		<3.3	<5.0	<5.0	<5.0	NA	<1.0	<1.0	<77
2-Butanone (MEK)		<17	<25	<25	<25	NA	<5.0	0.52J	<380
Carbon Disulfide		<3.3	<5.0	<5.0	<5.0	NA	<1.0	<1.0	<77
Carbon tetrachloride		2.1 J	<5.0	<5.0	<5.0	NA	<1.0	<1.0	<77
Chlorobenzene		<3.3	<5.0	<5.0	<5.0	NA	0.33 J	<1.0	<77
Chloroform		0.97 J	<5.0	<5.0	<5.0	NA	<1.0	<1.0	<77
Chloromethane		<3.3	<5.0	<5.0	<5.0	NA	<1 0	<1.0	<77
1,1-Dichloroethane		<3.3	<5.0	<5.0	<5.0	NA	**1.2**	<1.0	<77
1,2-Dichloroethane		<3.3	<5.0	<5.0	<5.0	NA	<1.0	<1.0	<77
cis-1,2-Dichloroethene		**9.2**	**6.9**	**7.7**	**9.0**	NA	<1.0	<1 0	48 J
trans-1,2-Dichloroethene		**4.1**	3.4 J	4.6 J	4.1 J	NA	<1.0	<1 0	<77
1,1-Dichloroethene		<3.3	<5.0	< 5.0	<5.0	NA	**9.1**	<1 0	<77
Methylene chloride		**3.4**	<5.0	< 5.0	<5.0	NA	<1.0	<1.0	<77
Methyl tert-butyl ether (MTBE)		<17	<25	<25	<5.0	NA	<5.0	<5.0	<380
1,1,2,2-Tetrachloroethane		**11**	<5.0	**15**	**12**	NA	<1.0	<1.0	**2100**
Tetrachloroethene		**5.4**	4.0 J	3.1 J	**5.9**	NA	0.24 J	<1.0	<77
Toluene		<3.3	<5 0	< 5.0	<5.0	NA	0.64 J	<1 0	<77
1,1,1-Trichloroethane		<3.3	<5.0	<5.0	<5.0	NA	**4**	<1 0	<77
1,1,2-Trichloroethane		<3.3	<5.0	< 5.0	<5.0	NA	<1 0	<1 0	<77
Trichloroethene		**76**	**70**	**78**	**92**	NA	<1.0	<1 0	**1000**

J = estimated result. Result less than reporting limit
BGS = below ground surface
* = Sample depth at MW-44 based on total depth measurement
of 72.89' below top of casing on 8/17/04

TABLE 2

SUMMARY OF VOLATILE ORGANIC COMPOUNDS IN GROUNDWATER SAMPLES
DDMT, Dunn Field
August and October 2004

Constituents	Well Number	MW-155	MW-155	MW-156	MW-157	MW-158	MW-158	MW-158A	MW-158A
	Sample ID	MW-155, 2.5 ft	MW-155, 10ft	MW-156	MW-157	MW-158	MW-158	MW-158A	MW-158A
	Approximate Sample Depth (ft. bgs)	79	86.8	67.7	75.5	92.5	99	80	86
	Date Sampled	10/13/2004	10/13/2004	8/20/2004	8/18/2004	10/9/2004	10/13/2004	10/10/2004	10/12/2004
Volatile Organic Compounds-SW846 8260B (µg/L)									
Acetone		<500	<500	2.9 J	8.7 J	2.8 J	<5.0	<100	<75
Benzene		<100	<100	0.23 J	<6.7	<1.0	<1.0	<20	<15
Bromodichloromethane		<100	<100	0.21 J	<6.7	<1.0	<1.0	<20	<15
Bromoform		<100	<100	0.87J	<6.7	<1.0	<1.0	<20	<15
2-Butanone (MEK)		<500	<500	0.47 J	<33	<5.0	<5.0	<100	<75
Carbon Disulfide		<100	<100	<1.0	<6.7	<1.0	<1.0	<20	<15
Carbon tetrachloride		<100	<100	<1.0	**9.4**	<1.0	<1.0	<20	<15
Chlorobenzene		<100	<100	<1.0	<6.7	<1.0	<1.0	<20	<15
Chloroform		<100	<100	0.42 J	**14**	0.47 J	0.29 J	<20	<15
Chloromethane		<100	<100	<1.0	<6.7	<1.0	<1.0	<20	<15
1,1-Dichloroethane		<100	<100	<1.0	<6.7	<1.0	<1.0	<20	<15
1,2-Dichloroethane		<100	<100	<1.0	<6.7	<1.0	<1.0	<20	<15
cis-1,2-Dichloroethene		**55 J**	**35 J**	<1.0	11	**2.2**	**3.0**	**27**	**43**
trans-1,2-Dichloroethene		<100	<100	<1.0	1.9 J	**1.1**	**1.3**	9.0 J	17
1,1-Dichloroethene		<100	<100	<1.0	<6.7	<1.0	<1.0	<20	<15
Methylene chloride		<100	<100	<1.0	2.8 J	<1.0	<1.0	<20	<15
Methyl tert-butyl ether (MTBE)		<100	<100	<5.0	<33	<5.0	<1.0	<100	<75
1,1,2,2-Tetrachloroethane		**2000**	**1500**	<1.0	5.7 J	**15**	**21**	**560**	**270**
Tetrachloroethene		<100	<100	<1.0	1.9 J	**1.2**	**1.8**	< 20	5.7 J
Toluene		<100	<100	<1.0	<6.7	<1.0	<1.0	< 20	<15
1,1,1-Trichloroethane		<100	<100	<1 0	<6.7	<1.0	<1.0	<20	<15
1,1,2-Trichloroethane		<100	<100	<1.0	<6.7	<1.0	<1.0	< 20	<15
Trichloroethene		**1000**	**950**	<1.0	**120**	**20**	**30**	**340**	**360**

J = estimated result. Result less than reporting limit
BGS = below ground surface
* = Sample depth at MW-44 based on total depth measurement
of 72.89' below top of casing on 8/17/04

TABLE 2

SUMMARY OF VOLATILE ORGANIC COMPOUNDS IN GROUNDWATER SAMPLES
DDMT, Dunn Field
August and October 2004

Constituents	Well Number	MW-159	MW-160	MW-161	MW-161	MW-162	MW-163	MW-164
	Sample ID	MW-159	MW-160	MW-161	DFTCIRADUP-1	MW-162	MW-163	MW-164
	Approximate Sample Depth (ft. bgs)	89	82	79.9	79 9	84	75.5	73
	Date Sampled	10/11/2004	10/13/2004	10/12/2004	10/12/2004	10/12/2004	10/14/2004	10/15/2004
Volatile Organic Compounds-SW846 8260B (µg/L)								
Acetone		<750	<50	<250	<5.0	<500	<500	<12
Benzene		<150	<10	<50	<1.0	<100	<100	<2.5
Bromodichloromethane		<150	<10	<50	<1.0	<100	<100	<2.5
Bromoform		<150	<10	<50	<1.0	<100	<100	<2.5
2-Butanone (MEK)		<750	<50	<250	<5.0	<500	<500	<12
Carbon Disulfide		<150	<10	<50	<1.0	<100	<100	<2.5
Carbon tetrachloride		<150	<10	<50	0.82 J	<100	<100	**4.0**
Chlorobenzene		<150	<10	<50	<1.0	<100	<100	<2.5
Chloroform		<150	<10	<50	**1.4**	<100	<100	**9.1**
Chloromethane		<150	<10	<50	<1.0	<100	<100	<2.5
1,1-Dichloroethane		<150	<10	<50	<1.0	<100	<100	<2.5
1,2-Dichloroethane		<150	<10	<50	<1.0	<100	<100	<2.5
cis-1,2-Dichloroethene		**100 J**	**31**	**31 J**	**44 J**	**62 J**	**41 J**	**6.3**
trans-1,2-Dichloroethene		<150	**17**	<50	**8.7**	<100	<100	0.97J
1,1-Dichloroethene		<150	<10	<50	<1.0	<100	<100	<2.5
Methylene chloride		<150	<10	<50	<1.0	<100	<100	<2.5
Methyl tert-butyl ether (MTBE)		<750	<10	<250	<5.0	<500	<100	<2.5
1,1,2,2-Tetrachloroethane		**3500**	**30**	**3100**	**3000**	**1700**	**4800**	<2.5
Tetrachloroethene		<150	**12**	<50	**5.9**	<100	<100	<2.5
Toluene		<150	<10	<50	<1.0	<100	<100	<2 5
1,1,1-Trichloroethane		<150	<10	<50	<1.0	<100	<100	<2.5
1,1,2-Trichloroethane		<150	<10	<50	**6.8**	<100	<100	<2.5
Trichloroethene		**1700**	**240**	**1400**	**1100**	**1400**	**1700**	**60**

J = estimated result. Result less than reporting limit
BGS = below ground surface
* = Sample depth at MW-44 based on total depth measurement
of 72.89' below top of casing on 8/17/04

PREPARED/DATE: JMQ 10/26/04
CHECKED/DATE: JLP 11/02/04

TABLE 3

ZVI INJECTION LOCATIONS

Injection ID	Closest monitoring well location	Estimated Saturated Thickness (ft)	Estimated Water Elevation (ft. msl)	Estimated Clay Elevation (ft. msl)
ZVI-1	MW-158	26.6	215.55	189.0
ZVI-2	MW-159	25.6	215.60	190.0
ZVI-3	MW-159	24.7	215.70	191.0
ZVI-4	MW-159	23.8	215.80	192.0
ZVI-5	MW-54	20.8	215.80	195.0
ZVI-6	MW-158	24.6	215.60	191.0
ZVI-7	MW-155	22.6	215.60	193.0
ZVI-8	MW-54	21.8	215.75	194.0
ZVI-9	MW-155	21.8	215.75	194.0
ZVI-10	MW-155	16.0	216.00	200.0
ZVI-11	MW-155	20.8	215.75	195.0
ZVI-12	MW-54	16.0	216.00	200.0
ZVI-13	MW-160	14.3	216.25	202.0
ZVI-14	MW-150	12.4	216.40	204.0

Notes:

1. Estimated water elevations for wells are from **Figure 1** Monitoring well and Proposed Injection Point Locations.
2. Estimated clay elevations are taken from **Figure 3** Estimated Top of Uppermost Clay in the Jackson Formation/Upper Claibourne Group.
3. Actual surface elevations for the injection locations will be obtained by survey.

PREPARED/DATE: KRA 11/01/04
CHECKED/DATE: JLP 11/02/04

TABLE 4

MONITORING WELLS FOR WATER LEVEL MEASUREMENTS
DDMT, Dunn Field
August and October 2004

	Baseline			Post Injection	
	August	**October**	**November**	**January**	**March**
MW6	X	X		X	X
MW7	X	X		X	X
MW10	X	X		X	X
MW15	X	X		X	X
MW29	X	X		X	X
MW30	X	X		X	X
MW31	X	X		X	X
MW32	X	X		X	X
MW33	X	X		X	X
MW40	X	X		X	X
MW42	X	X		X	X
MW44	X	X		X	X
MW51	X	X		X	X
MW54	X	X		X	X
MW56	X	X		X	X
MW57	X	X		X	X
MW58	X	X		X	X
MW68	X	X		X	X
MW69	X	X		X	X
MW70	X	X		X	X
MW71	X	X		X	X
MW76	X	X		X	X
MW77	X	X		X	X
MW78	X	X		X	X
MW79	X	X		X	X
MW80	X	X		X	X
MW91	X	X		X	X
MW95	X	X		X	X
MW126	X	X		X	X
MW127	X	X		X	X
MW144	X	X	X	X	X
MW145	X	X		X	X
MW147	X	X		X	X
MW148	X	X		X	X
MW149	X	X		X	X
MW150	X	X		X	X
MW151	X	X		X	X
MW152	X	X	X	X	X
MW153	X	X		X	X
MW154	X	X		X	X
MW155	X	X		X	X
MW156	X	X		X	X
MW157	X	X		X	X
MW158		X		X	X
MW158A		X		X	X
MW159		X		X	X

TABLE 4

MONITORING WELLS FOR WATER LEVEL MEASUREMENTS
DDMT, Dunn Field
August and October 2004

	Baseline			Post Injection	
	August	**October**	**November**	**January**	**March**
MW160		X		X	X
MW161		X		X	X
MW162		X		X	X
MW163		X		X	X
MW164		X		X	X
MW165			X	X	X
MW165A			X	X	X
MW166			X	X	X
MW166A			X	X	X
MW167			X	X	X
MW168			X	X	X
MW168A			X	X	X
MW169				X	X
MW170				X	X
MW171				X	X

PREPARED/DATE: KRA 11/01/04
CHECKED/DATE: JLP 11/01/04

TABLE 5

MONITORING WELLS FOR GROUNDWATER SAMPLING
DDMT, Dunn Field

	Baseline			Post Injection	
Well ID	**August**	**October**	**November**	**January**	**March**
MW-31	X				
MW-32	X				
MW-44	X				
MW-54	X			X	X
MW-70	X				
MW-76	X				
MW-77	X				
MW-79	X			X	X
MW-80	X				
MW-144	X			X	X
MW-145	X				
MW-147	X				
MW-148	X			X	X
MW-149	X			X	X
MW-150	X			X	X
MW-151	X			X	X
MW-152	X	X		X	X
MW-153	X				
MW-154	X				
MW-155	X	X	X	X	X
MW-156	X				
MW-157	X			X	X
MW-158		X	X	X	X
MW-158A		X	X	X	X
MW-159		X	X	X	X
MW-160		X		X	X
MW-161		X			
MW-162		X			
MW-163		X			
MW-164		X			
MW-165			X	X	X
MW-165A			X	X	X
MW-166			X	X	X
MW-166A			X	X	X
MW-167			X	X	X
MW-168			X	X	X
MW-168A			X	X	X
MW-170					
MW-171					

PREPARED/DATE: KRA 11/01/04
CHECKED/DATE: JLP 11/02/04

TABLE 6

GROUNDWATER ANALYTICAL PARAMETERS

	FIELD				
		Baseline		Post Injection	
	August	**October**	**November**	**January**	**March**
Carbon Dioxide[a]		X	X	X	X
Ferrous Iron[a]		X	X	X	X
pH	X	X	X	X	X
Specific Conductivity	X	X	X	X	X
Turbidity	X	X	X	X	X
DO (flow cell)	X	X	X	X	X
Temperature	X	X	X	X	X
Redox Potential	X	X	X	X	X

	LAB				
		Baseline		Post Injection	
	August	**October**	**November**	**January**	**March**
VOC's	X	X	X	X	X
Anion's/Alkalinity		X	X	X	X
Total Organic Carbon		X	X	X	X
Dissolved Organic Carbon		X	X	X	X
Sulfide		X	X	X	X
Total Metals (Arsenic, Manganese, Ca Mg, Selenium, Iron)		X	X	X	X
Methane/Ethene/Ethane		X	X	X	X
Dissolved Metals (Fe)		X	X	X	X
Carbon Dioxide[b]		X	X	X	X

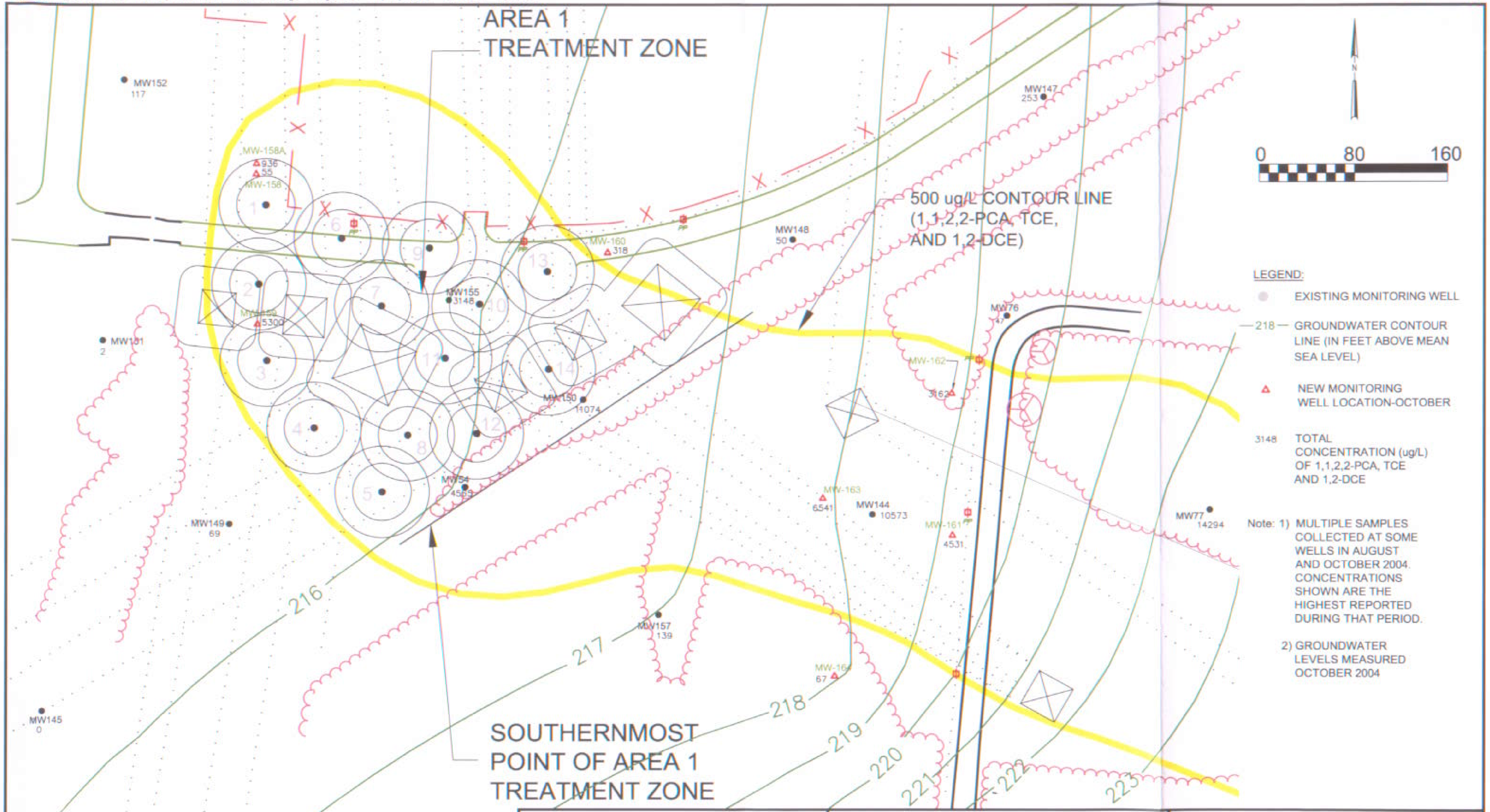
a Conducted with a field test kit

b 10% of samples will be analyzed for carbon dioxide in the laboratory to calibrate field results

PREPARED/DATE: KRA 11/01/04
CHECKED/DATE: JLP 11/02/04

FIGURES

J:\DDMT\DUNN FIELD-TOPO\TREATMENT-ZONE-4.dwg - Layout2 11/11/2004 12:06pm ralexand



DEFENSE DISTRIBUTION DEPOT
(MEMPHIS)

MACTEC
Engineering and Consulting, Inc.
3200 TOWN POINT DRIVE, SUITE 100
KENNESAW, GEORGIA 30144 (770) 421-3400

MONITORING WELL AND PROPOSED
INJECTION POINT LOCATIONS

JOB NO. 6301-04-0019

FIGURE 1

PREPARED BY/DATE

CHECKED BY/DATE

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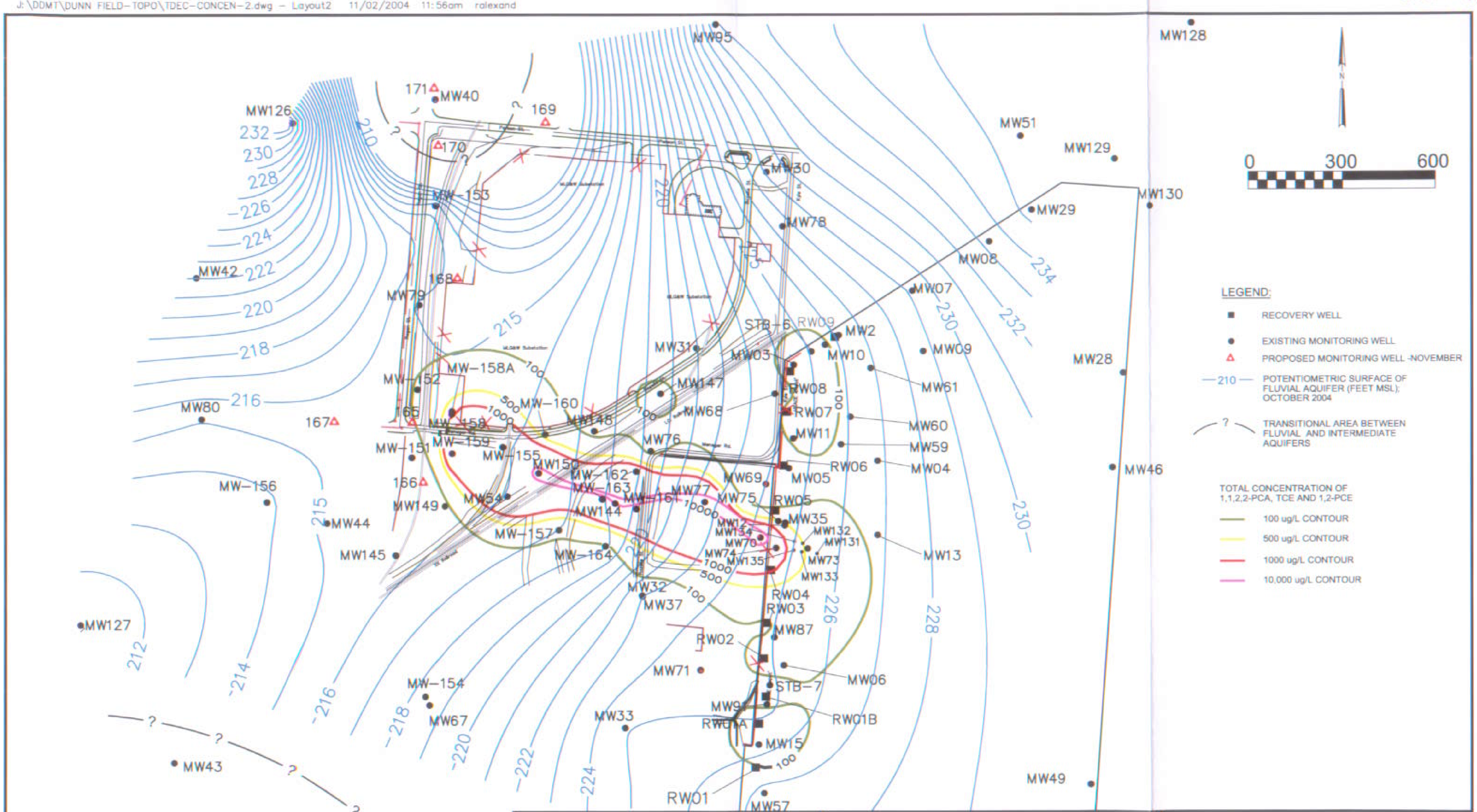

LEGEND:

- ■ RECOVERY WELL
- ● EXISTING MONITORING WELL
- △ PROPOSED MONITORING WELL -NOVEMBER
- —210— POTENTIOMETRIC SURFACE OF FLUVIAL AQUIFER (FEET MSL); OCTOBER 2004
- ? TRANSITIONAL AREA BETWEEN FLUVIAL AND INTERMEDIATE AQUIFERS

TOTAL CONCENTRATION OF 1,1,2,2-PCA, TCE AND 1,2-PCE

- 🟩 100 ug/L CONTOUR
- 🟨 500 ug/L CONTOUR
- 🟥 1000 ug/L CONTOUR
- 🟪 10,000 ug/L CONTOUR

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POTENTIOMETRIC SURFACE
OF THE FLUVIAL AQUIFER
DUNN FIELD
OCTOBER 14-15, 2004

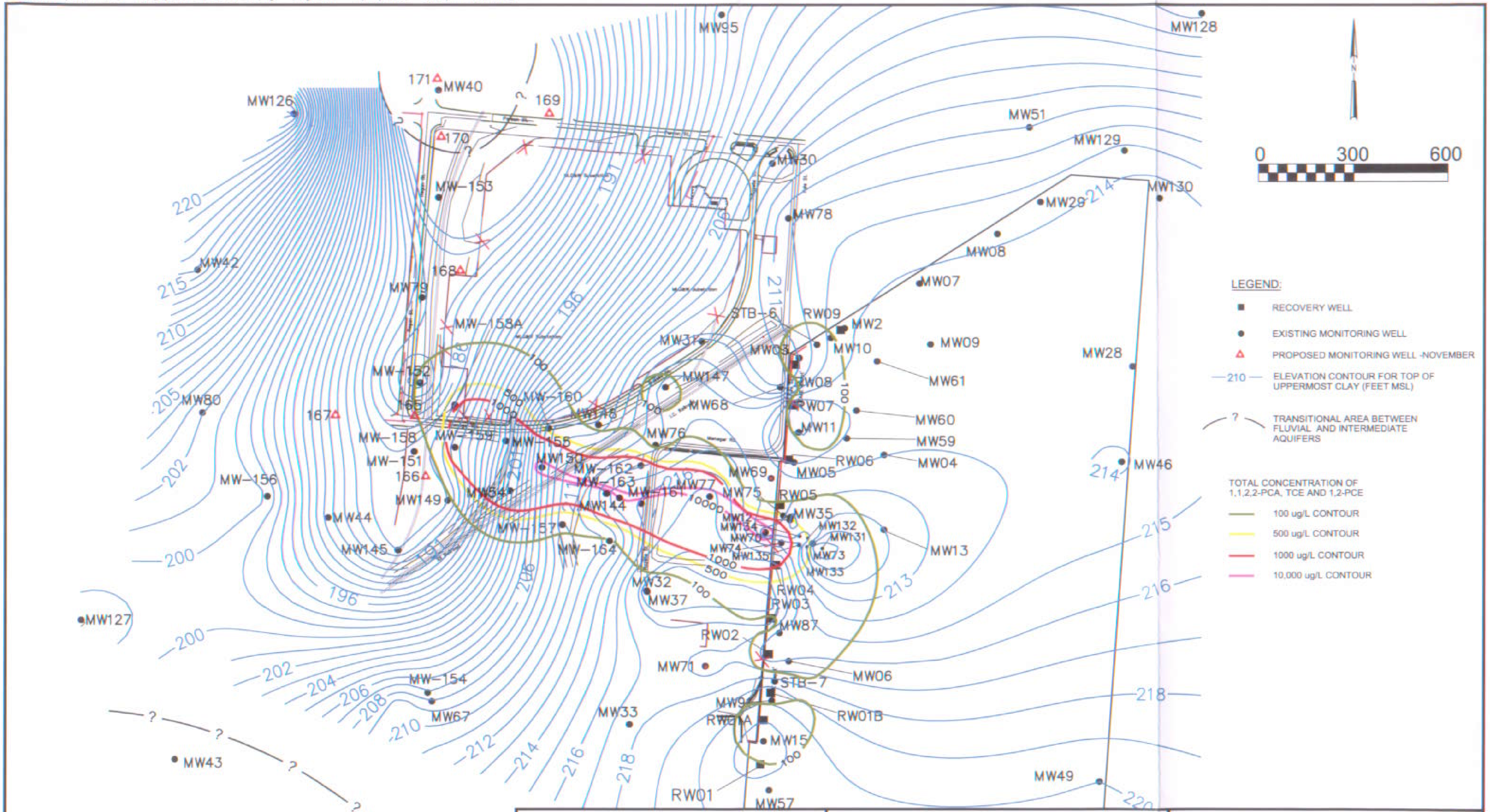
JOB NO. 6301-04-0019

FIGURE 2

PREPARED BY/DATE

CHECKED BY/DATE

812 39



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ESTIMATED TOP OF UPPERMOST CLAY
IN THE JACKSON FORMATION/UPPER
CLAIBOURNE GROUP
MEMPHIS DEPOT, DUNN FIELD

JOB NO. 6301-04-0019 FIGURE 3

PREPARED BY/DATE
CHECKED BY/DATE

APPENDIX A

ARS WORK PLAN

ARS TECHNOLOGIES, INC.

BREAKING NEW GROUND IN ENVIRONMENTAL TECHNOLOGY

FEROX^{sm} FIELD INJECTION WORKPLAN

Memphis Defense Depot – Dunn Field
Memphis, Tennessee

Submitted to:

MACTEC ENGINEERING AND CONSULTING
3200 Town Point Drive NW, Suite 100
Kennesaw, GA 30144

November 12, 2004

Prepared by:

ARS Technologies, Inc.
114 North Ward Street
New Brunswick, New Jersey 08901

Table of Contents

FIGURES

ACRONYMS

ARS	ARS Technologies, Inc.
bgs	Below Ground Surface
COC	Contaminant of Concern
CVOC	Chlorinated Volatile Organic Compound
1,1-DCA	1,1-dichloroethane
1,2-DCE	1,2-dichloroethene
EPA	Environmental Protection Agency
LAI	Liquid Atomized Injection
1,1,2,2-PCA	1,1,2,2-Tetrachloroethane
PCE	Tetrachloroethene
PF	Pneumatic Fracturing
PRB	Permeable Reactive Barrier
PSTA	Pilot Study Treatment Area
RI/FS	Remedial Investigation/Feasability Study
ROI	Radius of Influence
SOW	Statement of Work
1,1,2-TCA	1,1,2-Trichloroethane
TCE	Trichloroethene
VC	Vinyl Chloride
VOC	Volatile Organic Compound
ZVI	Zero-Valent-Iron

1.0 INTRODUCTION

The work plan presented herein outlines the tasks and technical approaches associated with the installation of a Ferox^{sm} Treatment Zone (FTZ) at the Former Defense Distribution Depot in Memphis, Tennessee. This work plan also provides a brief discussion on general site information and geological characteristics relevant to the technology application.

The Ferox^{sm} injections will be implemented within Area 1, which is located northwest of Dunn Field. Area 1 extends from Canadian National (CN) railroad tracks northwest to the Memphis Gas, Light and Water electrical substation and is bisected by Menager Avenue. The area encompasses monitoring wells MW-54, MW-150 and MW-155. This work plan was written in accordance with MACTEC's Scope of Work entitled "Early Implementation of Selected Remedy, Dunn Field Defense Depot", Contract No. 6301040002 and associated documents emailed to ARS between August and October 2004.

Based on information provided in the SOW, it is our understanding of the project objective is to achieve 90% reduction of the target contaminants within Area 1 using the Ferox^{sm} process. The scope will involve the installation of a FTZ to facilitate the *in-situ* abiotic chemical reduction of the primary Contaminants of Concern (COCs), consisting of TCE and 1,1,2,2-PCA. Reduction of the COCs will be accomplished through the injection and distrubution of highly reactive Zero Valent Iron (ZVI) powder utilizing ARS' Ferox^{sm} and Liquid Atomization Injection (LAI) remedial processes.

2.0 SITE BACKGROUND

The Memphis Depot is located in southeastern Memphis, Tennessee. The Depot originated as a military facility in the early 1940's. In 1995, the Depot was placed on the list of Department of Defense facilities to be closed under the Base Realignment and Closure. On October 14, 1992, the Depot was placed on the National Priorities List by the U.S. Environmental Protection Agency (EPA), bringing the facility within the Federal Superfund program.

2.1 Geology/Hydrogeology

The soils underlying the designated treatment area consist of loess (silts and clays) from grade to approximately 30 feet bgs followed by fluvial deposits consisting predominantly of sands mixed with gravel to an approximate depth of 95 feet bgs. The fluvial deposits are underlain by low-permeability clays of the Jackson Formation/Upper Claiborne Group, which serve as a hydraulic barrier to the downward migration of groundwater within the overlying fluvial aquifer.

The saturated thickness of the fluvial aquifer varies across Dunn Field and is controlled by the configuration of the underlying clay layers. Maximum saturated thickness of the fluvial aquifer in Area 1 ranges between 10 and 30 feet. Depth to groundwater averages 80 feet bgs. In general, the aquifer flows in a westerly direction and follows the contours of the uppermost clay confining unit.

Ferox^{sm} injections will target the fluvial aquifer from an approximate depth of 70 to 100 feet bgs. Soil boring logs collected from monitoring well installations as part of the pilot study within the vicinity of MW-73 identified the fluvial aquifer to consist of fine to coarse sands with gravelly sands in the lower protions of the fluvial deposits.

3.0 TECHNOLOGY BACKGROUND

The patented Ferox^{sm} technology represents a significant advancement from the conventional Permeable .Reaction Barrier (PRB) technology since the technology is based on an innovative injection Liquid Atomization Injection (LAI) process in combination with a proprietary highly reactive ZVI powder product emplaced within the subsurface. The technology can effectively treat chlorinated volatile organic compounds (CVOCs) in a wide range of geologic formations and depth.

3.1 Ferox^{sm} Treatment Technology

ARS' Ferox^{sm} technology is a patented treatment process for the *in situ* reduction of halogenated organic compounds. The Ferox^{sm} technology consists of the multi-phase injection and emplacement of specific quantities of a highly reactive ZVI powder into subsurface contaminant zones.

The chemical processes of ZVI in treating CVOCs have been well documented and proven. Ferox^{sm} provides an active and direct chemical reduction of the compounds in contrast to indirect processes such as enhanced bioremediation, bio-stimulation, bio-augmentation, etc., the success of which depends greatly on many *in situ* inter-related factors beyond engineering control. Furthermore, the presence of the iron in the aquifer creates an *in situ* environment favorable to biological processes, which may provide a secondary treatment mechanism. In addition, with its long resident reaction life, treatment remains active for a period of several years to address additional contaminant mass loading that may result from the presence of residual contamination.

The significant advantages of Ferox^{sm} over other *in situ* treatment methods is its long reaction life and its inherent ability to provide direct chemical treatment of the target organics while creating a favorable *in situ* environment for biological processes. These benefits provide an inherent engineering factor of safety to address varied contaminant loading conditions, which are commonly found at halogenated hydrocarbon sites located within low permeability geologic formations. In addition, once the Ferox^{sm} system is installed, there are no above ground systems that require ongoing utilities, O&M and interference with long-term plant operations.

The ZVI powder used in the Ferox^{sm} application is a reduced sponge iron powder. As a result of its manufacturing process, this specialty iron contains internal porosities (hence the name "sponge" iron) that significantly increase its total surface area and enhance its reactivity. In addition, due to its high purity, the material is certifiable as Food-Grade and has been approved for use in many states. ARS has documented the superior reactivity of this type of powder through the performance of laboratory tests.

ARS' confidence in the Ferox^{sm} process is substantiated by our direct experience in applying the technology at more than twelve DOD facilities. Included within these sites are successful technology applications at the Memphis Depot's Dunn Field, the Navy's MCLB Site in Albany, Georgia, Arnold Air Force Base in Tennessee, Hunter's Point Shipyard in San Francisco and NASA's Marshall Space Flight Center in Huntsville, Alabama.

3.2 Liquid Atomized Injection

A critical component of the Ferox^{sm} process is ensuring that the ZVI is distributed effectively within the subsurface to facilitate treatment. To accomplish this distribution, ARS incorporates a gas-based Liquid Atomized Injection (LAI) delivery approach for the emplacement of the ZVI. Under this approach, the ZVI slurry is introduced into a high flow, high-velocity gas stream where the slurry becomes atomized into an aerosol with characteristics more closely resembling that of a gas instead of an incompressible fluid.
The atomized multi-phase injection approach provides several key benefits over conventional injection techniques. These include:

1. Creation of anaerobic conditions in the injection pipe/nozzle to delay premature surficial iron oxidation during the injection process by the use of nitrogen gas as the carrier fluid
2. Aggressive mixing / recirculation maintains the iron powder in uniform suspension and allows for the reaction of the iron powder with water to be accelerated
3. Allows the iron powder to be injected into the formation to significant radial distances.

Depending upon the permeability or heterogeneities within the geologic zone, Pneumatic Fracturing (PF) may be used as a precursor to injection of the ZVI powder. PF can be described as a process whereby a gas (usually nitrogen) is injected into the subsurface at pressures exceeding the natural *in situ* pressures (i.e. overburden pressure, cohesive stresses, etc.) and at flow volumes exceeding the natural permeability of the formation. In consolidated formations (including bedrock and some silt and clay formations) the result is the enhancement of existing fractures and planes of weakness (for example joints, bedding planes, laminated clays, etc) and the propagation of a fracture network surrounding the injection well. In turn, this fracture network enhances the overall effective bulk permeability of the formation thus allowing the selected *in situ* treatment approach to work more effectively.

3.2.1 Emplacement Mechanism

Physical characteristics of a soil will typically govern the emplacement mechanism of the ZVI powder. These mechanisms can be characterized into three categories; dispersion, fluidization, or fracture filling (**Figure 1**). In porous materials such as gravel, the injection of iron powder will result in the dispersion around soil or rock particles, and will travel as far as the gas carrying the particle maintains enough energy to keep it from settling. In loose sand deposits, the injection of high volumes of gas and slurry will result in local fluidization of the formation causing iron particles to get "mixed" within the soil matrix. In more cohesive soils such as clays and silts, the high volume/pressure injections will result in PF of the formation. The emplacement of iron will be governed by the flow of gas in the fractures and the iron particles will settle as the kinetic energy decreases. In field applications of the injection process, iron powder emplacement within a geologic formation will typically exhibit more than one of these mechanisms.

4.0 PROJECT TASK SCOPE

To effectively accomplish the project objectives outlined in the SOW, several key tasks will need to be completed. ARS will strive to perform all of the field related tasks summarized below as safely and efficiently as possible. These specific tasks are discussed in more detail throughout the remainder of the implementation plan. The following summarizes the anticipated sequence of field activities along with the related tasks.

1. Mobilization/Site Setup
2. Injection Boring Installation
3. Ferox^{sm} Injections
4. Site Breakdown

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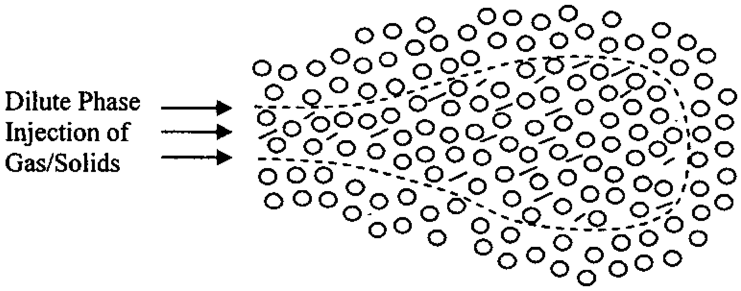
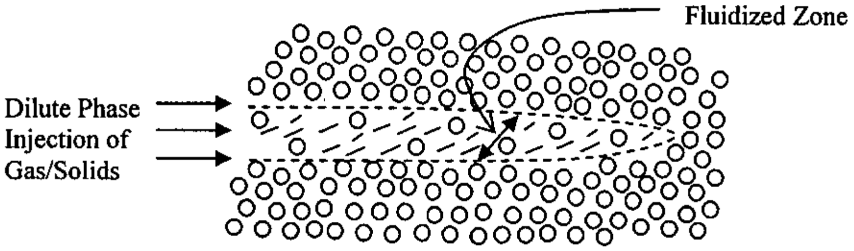
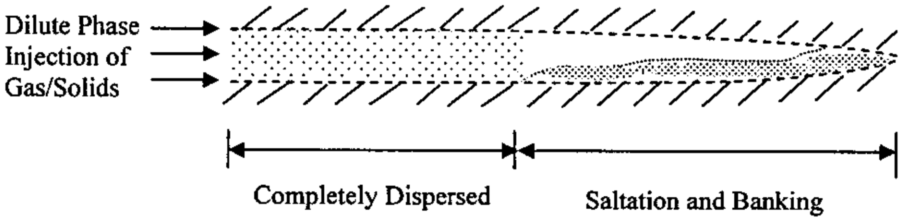
Figure 1. Subsurface Transport Mechanisms



a) Iron slurry travels through formation through the intergranular pore spaces



b) High volumes of gas cause fluidization of formation, causing iron to mix with soil



c) Iron powder is emplaced within the dilated fracture

5.0 INJECTION BORING INSTALLATION

ARS will be responsible for the subcontracting and supervision of all drilling operations relating to injection boring installation. Injection well installation will be accomplished using established rotasonic drilling methods. Boart Longyear of Little Falls, Minnesota will be contracted by ARS to perform all drilling related tasks associated with the Ferox^{sm} injections.

5.1 Injection Well and Monitoring Well Layout

A total of fourteen (14) temporary injection borings will be installed on approximate 60 to 80 ft centers, correlating to a 25 ft Radius Of Injection (ROI) and a 40 ft Radius of Influence as described in the Dunn Field treatability study. This gives an approximate treatment area of 25,500 ft^2. The proposed injection well layout presented in **Figure 2** will target the CVOCs within the 500 µg/L contour. Injection locations are to be cleared for utilities and accessibility by MACTEC prior to mobilization; any changes to the locations will be approved by the MACTEC project manager in advance.

5.2 Injection Well Installation

To successfully apply the Ferox^{sm} technology, injection wells need to be installed and stabilized in such a way that injection equipment can be placed at the desired target depths and safely withdrawn when the injections are complete. To accomplish this, the injection boring installation will utilize conventional rotasonic soil coring combined with a pressurized water column technique to advance a 4-inch diameter casing to an approximate depth of 90 feet bgs. Direct coring will be performed within the upper loess deposits, which are expected to extend to an approximate depth of 30 - 50 ft. To ensure that the target depths are achieved, down-hole parameters consisting of water pressure and water flow will be closely monitored during casing advancement. A rapid increase or spike in water pressure combined with a reduced water flow will indicate the presence of a low permeable clay or silt unit. Under this approach, water pressure monitored during casing advancement will be used in conjunction with monitoring well logs to confirm that the upper extent of the low-permeable clays of the Jackson Formation/Upper Claiborne Group has been reached. By monitoring water flow, an estimate will be made on the total water volume required to advance the casing to the target depths. Boring logs for wells in the vicinity of Treatment Area 1 will also be used to assist in predicting depths to the top of clay.

In the event that casing lockup occurs down hole during advancement and/or between injections, a 6-inch override will be advanced to retrieve the 4-inch casing. Once the 4-inch casing is retrieved, injections will take place within the 6-inch override.

6.0 FEROX^{SM} INJECTION OPERATIONS

Due to the overall complexity of the fluvial aquifer soils at the site, the Ferox^{sm} injections will be directly integrated with established rotasonic drilling techniques into one streamlined process. This approach has been used successfully at similar sites including the Pilot Study demonstration at Dunn Field. This approach will provide added down-hole flexibility ensuring the required dosages of ZVI are effectively dispersed within the target treatment intervals.

A critical component of the Ferox^{sm} process is ensuring that the ZVI is distributed effectively within the subsurface to facilitate contaminant destruction. To accomplish this distribution, ARS incorporates a gas-based delivery approach for the emplacement of the ZVI. Depending upon the permeability or heterogeneities within the geologic zone, Pneumatic Fracturing (PF) may be used as a precursor to injection of the ZVI powder.

ARS' PF technology is directly integrated with the LAI process. Upon initiation of the field injections, an evaluation will be made to determine whether PF is being applied within the target intervals. This will be accomplished through an evaluation of down-hole injection pressures relative to time. The data will be collected through an in-line data logging system fitted with a series of pressure transducers, which collect down-hole pressure every 1/8th of a second. If it is determined that fracturing is occurring, then additional data parameters will be monitored to assess the distances and orientation of injection fluid propagation and identify the subsurface delivery mechanism.

6.1 Liquid Atomized Injection Procedures

The LAI technology involves the blending of a desired reagent into a high flow nitrogen gas stream. The initial blending of reagent and gas initially occurs at the surface. Once blended, the three-phase material (water-reagent-gas) is routed down-hole and injected through a proprietary high velocity nozzle. As the injected media enters the nozzle the reagents become instantaneously atomized and dispersed through the formation. A simplified schematic of the PF/Ferox^{sm} is shown in **Figure 3**.

The PF/LAI system is housed on a 4-foot-by-8-foot skid and consists of a gas injection control manifold and a digital data logger used to monitor various operational parameters. If required, the target intervals will be pneumatically factured using pressurized nitrogen as the fracturing/atomization fluid. A series of bulk nitrogen "tube" trailers will be mobilized to the site for this operation. In addition, a pumper truck will be utilized to maintain a sufficient bank pressure during the injections. The compressed nitrogen will be routed through an injection manifold by a high-pressure hose. An injection hose will then be connected from the injection manifold to a proprietary down-hole injector, which will be lowered inside the sonic casing to the desired depth. ARS will document any changes associated with the injection interval and corresponding changes in iron dosages. This information will be included in the daily reports.

Each injection location will be addressed starting at the deepest interval and working upward. Since the targeted soils consist primarily of sands, it is anticipated that the lower intervals, once completed, will collapse and serve as a bottom seal for the subsequent shallower injections. The outer casing will serve as a temporary conduit for direct access to the target depths. When the targeted dosage of iron is emplaced at a specific interval, the packers will be deflated, and the exterior casing and nozzle assembly will be raised to the next injection interval. The targeted injection interval using the current injector configuration will be 24-inches. A schematic of the down-hole injector configuration is illustrated in **Figure 4**.

The Ferox^{sm} process involves mixing the ZVI at the surface with potable water to generate reactive slurry. Loading and mixing of the slurry is accomplished with a fully automated mixing console. The proportions of ZVI to water are programmed into the system to enable accurate batching. Once sufficiently mixed, the slurry is blended above ground directly into a nitrogen gas stream, where it is transferred under pressure down-hole and atomized through a proprietary nozzle (**Figure 4**). The manifold system provides accurate injection pressures at controlled flow rates, enabling ARS to achieve the optimal iron powder dispersion flow velocities.

Injection duration in each borehole will be directly dependent upon injection pressures, the quantity of iron desired within the specific zone and achievable down hole flow rates. High injection pressures will result in lower flow rates and as a result require more time to deliver the target dosage of ZVI. Borehole abandonment will be performed in accordance with applicable rules and regulations of the State of Tennessee. Grouting operations will be completed periodically using standard tremie grouting techniques.

6.1.1 Injection Monitoring Parameters

During injection operations, the following system operational parameters will be monitored and collected:

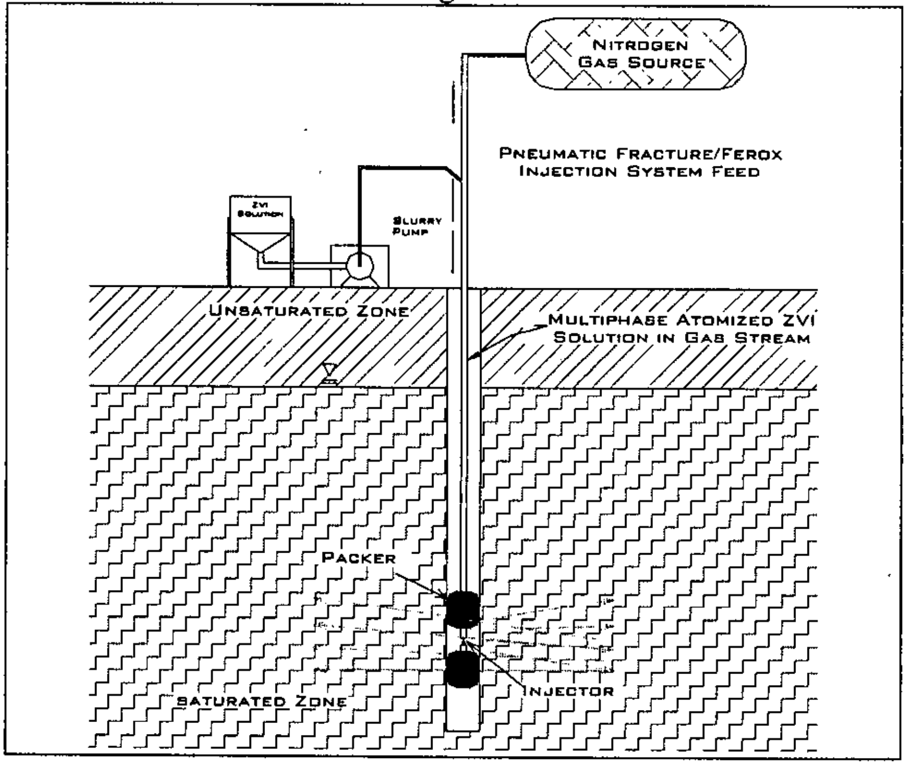
1. Down hole injection initiation and maintenance pressures;
2. Injection pressure influence at surrounding monitoring points, and
3. Ground surface heave adjacent to, and in the vicinity of the injection point.

Other visual observations during each injection will also be recorded. Detailed discussions of the operational parameters are provided below:

Injection Initiation and Maintenance Pressures

During each injection, a pressure transducer will be used to record data every 1/8 of a second. This data will be used to create a pressure-history curve from which the initiation pressure and the maintenance pressure can be determined. The initiation pressure represents the pressure at which the formation yields to the influx of injection fluid. The maintenance pressure represents the pressure required to maintain the injection flow into the formation. The graphical representation of this data plotted over time provides information as to the *in-situ* stresses of the formation corresponding to depth, as well as a confirmation that fractures were created and propagated.

Figure 3. Schematic of Pneumatic Fracturing/Ferox^{SM} Process



Pressure Influence at Adjacent Wells

During the injections, pressure gauges will be placed at wells near the injection points to monitor for pressure influence. Each pressure gauge is outfitted with a drag arm indicator that records the maximum pressure detected at the monitoring point during the injection.

In addition, visual observations will also be used to indicate pressure influence in surrounding wells.

Ground Surface Heave

Ground surface heave monitoring will be conducted during each injection using surveying transits in conjunction with a heave rod.. The heave rod will be placed at locations of varying radial distance from the fracture/injection well. During each injection event, the rod will be observed for the maximum amount of upward motion (surface heave) and the post-injection resting position (residual heave). Ground surface heave monitoring data provides additional information that can be used to assess the distances and orientation of injection fluid propagation.

6.1.2 Ferox^{sm} Injection Dosages

Ferox^{sm} injections in Area 1 will be applied within fourteen (14) temporary injection points installed approximately on 60 to 80 ft centers. The Vertical Target Treatment Zone (VTTZ) for each injection boring within Area 1 will range between 10 to 28 ft bgs and will be specified by MACTEC prior to mobilization. ARS is aware that the actual treatment zone thickness may vary slightly based on the depth to the bottom of the targeted zone (top of clay layer). The injection assembly will be set up to deliver the ZVI over discrete 24-inch intervals within each injection point for a total of 10 injections per location (assuming a 20 ft thick zone). The total VTTZ for Area 1 will not exceed 280 linear feet and the maximum continuous treatment interval for any one injection boring will not exceed 28 ft.

ARS has estimated that 189,000 lbs of ZVI will be required to reduce contaminant levels by roughly 90 percent. The ZVI powder will be evenly distributed amongst the target injection intervals. The ZVI quantity is based on an approximate ratio of 0.5 percent soil mass to iron mass. This ratio is derived from ARS' experience and represents the optimal target ZVI dosage similar to what was achieved during the Ferox^{sm} Pilot Phase Study at Dunn Field. Treatment of the cumulative 280 ft VTTZ will required 140 injection intervals (24-inch intervals). Within each interval, approximately 1,350 lbs of ZVI will be injected. The ZVI slurry will be prepared onsite within a 400-gallon batch tank located on ARS' high-pressure circulation/pumping trailer. The ZVI will be mixed at a target concentration of 4 pounds/gallon of water, which correlates to 337.5 gallons per interval. Hydrants located within the vicinity of Area 1 will supply water.

If borehole collapsing issues, loss of borehole seal, subsurface anomalies, complete saturation of the pore spaces and/or other subsurface conditions result: (a) in less than 75% of the target ZVI dosage being injected in all intervals within an injection boring; or (b) in less than 40% of the target ZVI dosage being injected in two adjacent intervals within an injection boring, then ARS will complete (remaining dosage/quantity) the injection at the appropriate depth intervals in an offset boring at no additional charge. No more than 150% of the target ZVI mass will be injected in a single interval.

ARS will provide a daily summary report in a short written format (paragraph or standard form) by 9 am central time documenting all activities performed the previous day. The report will include the injection locations and depth intervals completed with the quantities of iron injected per interval and the injection parameters. Any conditions outside those encountered in the pilot study and affecting the injection process will be identified, as will any changes in total projected quantities of iron and nitrogen. The daily reports will provide documentation for quantities of items 7) Zero Valent Iron material, 8) Nitrogen Gas, 9) Ferox^{sm} Injections and 10) Delay Time.

During injections operations, site-specific conditions may dictate the actual or optimal iron-to-water concentrations necessary to meet the project objectives and achieve a maximum ZVI distribution within the target areas. Under conditions where the injected slurry exceeds the capacity of the formation, daylighting or short-circuting can occur. This condition typically results in slurry/gas propagation to the surface through old boreholes or naturally occurring vertical fractures. ARS will attempt to meet the amount of ZVI targeted to provide the highest level of assurance for the treatment of the dissolved and residual CVOCs at the site. In the event the target ZVI dosages cannot be injected within a specific interval, increased loadings may be applied within other intervals that readily accept the target dosages. The MACTEC project manager must approve such changes in advance.

6.2 Field Equipment

The major pieces of equipment used to complete the work shall include:

- Fracture module
- Double-feed slurry/Ferox^{sm} injection system
- Injection/Packer assembly
- Nitrogen tube trailer
- Liquid Nitrogen Pumper Truck
- Two support vehicles
- Rotosonic drill rig
- Air compressor
- Generators
- Equipment trailer
- Decontamination equipment
- Forklift
- Water tanks

7.0 MONITORING AND PERFORMANCE VERIFICATION

MACTEC will be responsible for all baseline monitoring activities prior to the LAI and Ferox^{sm} injections. Pre-injection monitoring will provide representative baseline information to which the post-injection data can be compared. Monitoring activities will include obtaining groundwater samples for specific physical and chemical properties. During the injections, ARS will record operational parameters to ensure adequate dispersion of the iron powder within the formation.

7.1 Pre-Injection Monitoring

Pre-injection or baseline monitoring will be accomplished through the collection of groundwater from within the treatment area. Samples will be analyzed for pertinent parameters including, but not limited to CVOCs, chloride, pH, dissolved iron, redox, nitrate and sulfate.

7.2 Injection Monitoring

During the injection process, ARS personnel will monitor the quantity of slurry injected as well as the duration of injection. Typically, a single batch of iron powder slurry is mixed and injected at one time, and therefore exact quantities are recorded during each injection.

Injection pressures will be observed to ensure proper operation of the system and iron powder dispersion into the formation. Personnel will keep record of these and other operational parameters during the field activities.

8.0 DECON/WASTE DISPOSAL

MACTEC will be responsible for the management and proper disposal of all waste including soil cuttings, iron waste residuals, disposable personnel protective gear, decontamination water and overall general waste. All down-hole equipment will undergo decontamination within a designated area approved by MACTEC. ARS will assume all responsibility for the construction of all temporary decontamination facilities.

9.0 SCHEDULING

All necessary equipment, iron powder, and field materials will be mobilized to the site during the week of November 15, 2004. Approximately 33 working days will be needed to complete the field operations, including site setup, Ferox^{sm} injections, post-injection soil sampling, waste management and disposal and site breakdown. A field schedule has already been provided to MACTEC for review. The duration of the project will ultimately depend on the site conditions, borehole stability and the formation's ability to accept the injected volumes of slurry. During field operations, ARS will notify MACTEC of any delays that may prevent the timely performance of related activities.

On completion of the field demonstration, all data collected will be compiled and presented in a final report that will be submitted to MACTEC.

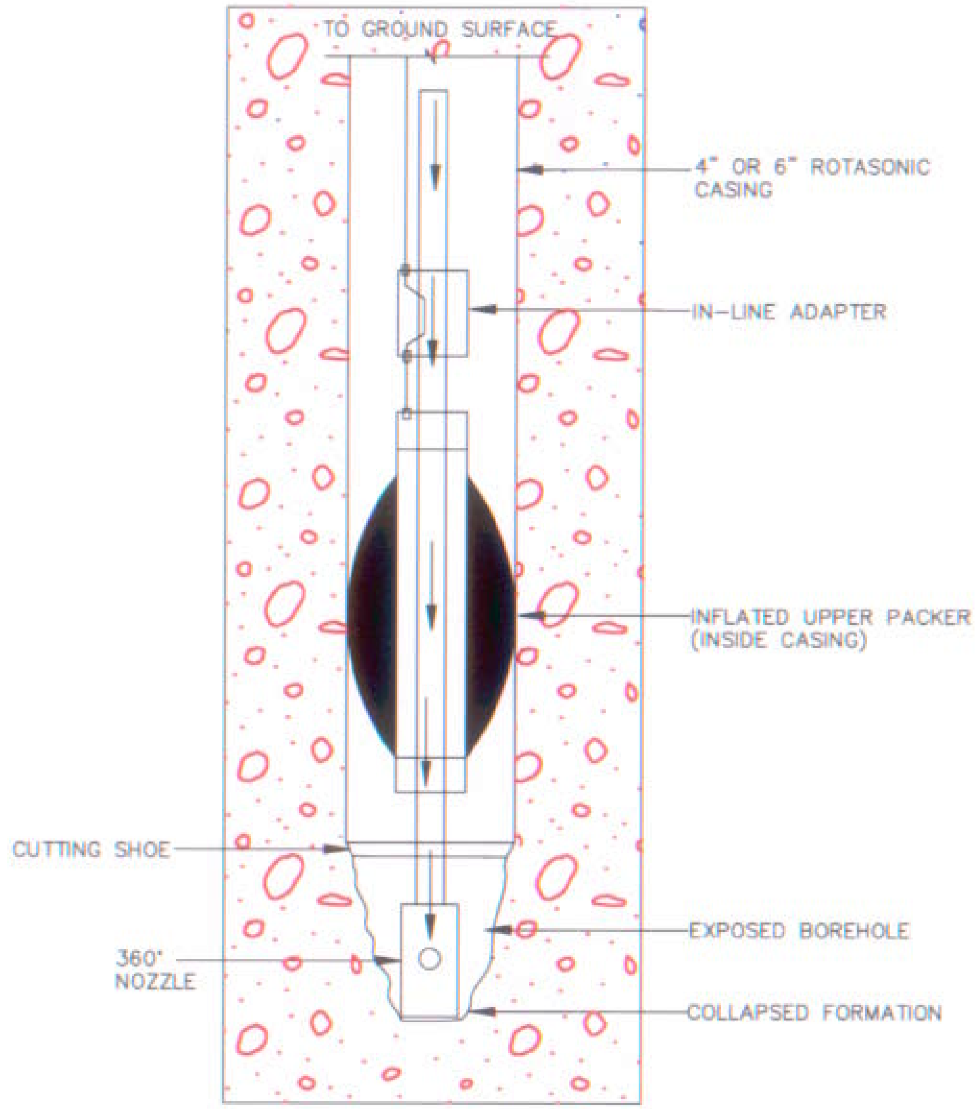
10.0 TECHNOLOGY MANAGEMENT AND STAFFING ORGANIZATION

This section presents the organizational structure of the management of the technology demonstration.

The following shows the key ARS personnel and their responsibilities:

Project Manager:	Michael Liskowitz
Project Engineer:	Michael Liskowitz
Senior Field Technicians:	Mike Cramer/John Martin
Site Health and Safety Officer:	William Beachell
Corporate Health and Safety Officer:	William Beachell

ARS will conduct the technology demonstration under the oversight of MACTEC.



SCENARIO 1 – SINGLE PACKER SYSTEM

ONE PACKER (ABOVE INJECTION NOZZLE) INSIDE ROTASONIC DRIVE CASING
(Assumes rapid formation collapse below the rotasonic cutting shoe and
maintenance of an adequate seal between the borehole wall and the drive casing)

FIGURE 4
CONCEPTUAL INJECTION PACKER
STRING CONFIGURATIONS

FIGURE 4-3

APPENDIX B

ARS MEETING AGENDA

Early Implementation of Selected Remedy
Dunn Field
Defense Depot Memphis, Tennessee

Meeting with ARS

November 3-4, 2004

AGENDA

DISCUSSION TOPIC

Project Planning, Design and Coordination
- ARS' Management Team
  - Primary Point of Contact
  - Secondary Point of Contact
  - Site Visits
- MACTEC's Management Team
  - Primary Point of Contact
  - Secondary Point of Contact
  - Site Visits
- ZVI Injection Design
  - Review ZVI Work Plan
  - Review Proposed Injection Locations

Submittal Status
- Work Plan
- Health and Safety Plan
- Schedule
- ZVI Certificate of Purity
- Well Driller's License
- Permits

Site Work Planning
- Mobilization
  - Water Supply
  - Decontamination Area
  - Restroom Facilities
- Scope of Work
  - Work Lay Down Areas
  - ZVI Handling and Storage
  - Injection Fluid Handling and Disposal
  - Equipment Decontamination
  - IDW Handling/Disposal
- Schedule Review
  - Hours of Operation
  - Work Schedule

DISCUSSION TOPIC
Quality Control • Management, Coordination, and Communication • Site Visits and Meetings • Technical Memorandum • Daily Summary Reports • Injection Performance Curves
Review of the HASP • Comment Review and Responses • Key Personnel • Site Control • Emergency Response • Hazard Communication
Site Inspection • Site Access • Utility Clearance • Primary/Secondary Injection Locations • Equipment Staging/Setup • Site Security • Injection Sequencing
General Discussion
Adjourn

APPENDIX C

BORING LOGS IN THE ZVI INJECTION AREA

CH2M HILL MONITORING WELL CONSTRUCTION LOG

Standard Flush Mount

Installation: DDMT

Site: West of Dunn Field

Project Number: 11363Ø.Ø1.ZZ

Drilling Contractor: Boart Longyear

Built By: Boart Longyear

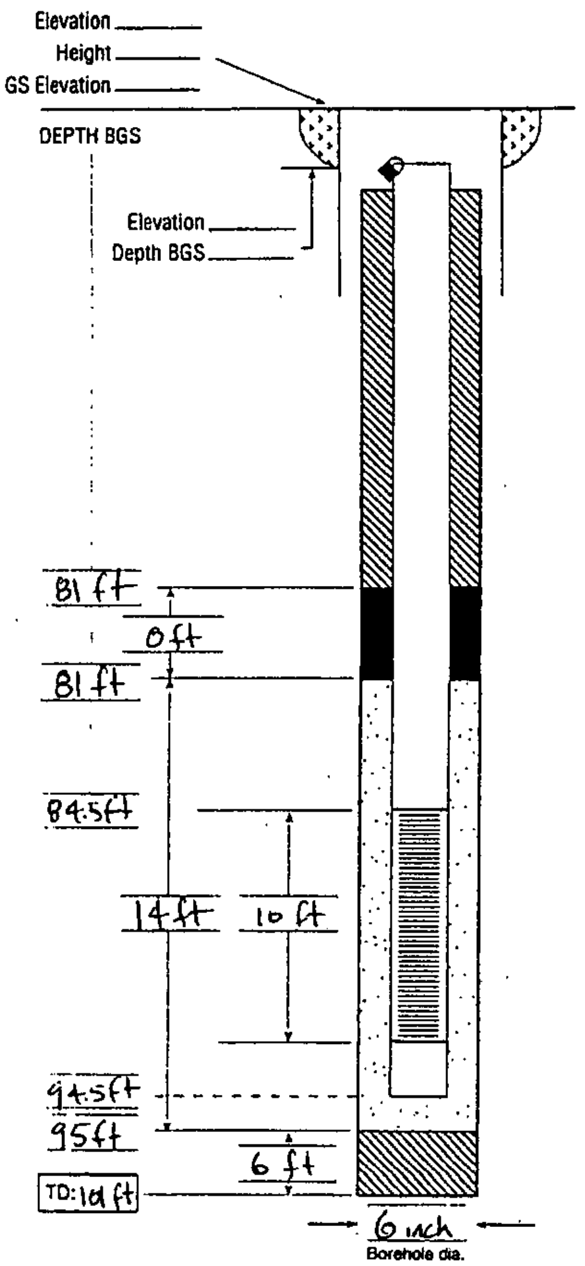
Well Number: MW-54 (J)

Client/Project: DDMT GW Investigation

Starting date: Ø9 FEB 96 time: Ø84Ø

Completion date: ______ time: ______

Well Coordinates: ______



PROTECTIVE CSG

Material / Type ______

Diameter ______ Water Tight Seal (Y / N)

Depth BGS ______ Weep Hole (Y / N)

SURFACE PAD

Composition & Size ______

RISER PIPE

Type: Schedule 40 PVC

Diameter: 2 inch

Total Length (TOC to TOS): 84.5 ft

GROUT

Composition & Proportions: High Solids (30%) Bentonite Clay - Pure Gold

Tremied ([✓ Y] N)

Interval BGS: 0 ft to 81 ft

CENTRALIZERS (Y [✓ N])

Depth(s) BGS ______

SEAL

Type: N/A

Source ______

Hydration Time ______ Volume of Fluid Added ______

Tremied (Y / N)

FILTER PACK

Type: 20/40 Silica Sand

Amount Used: 4 50 # bags

Tremied (Y / [✓ N])

Source: The Morie Company

Gr. Size Dist.: Grade 00N

SCREEN

Type: Schedule 40 PVC

Diameter: 2 inch

Slot Size & Type: 0.010 inch

Interval BGS: 84.5 ft to 94.5 ft

BACKFILL PLUG

Material: Bentonite Pellets

Hydration Time ______

Tremied (Y / [✓ N])

Proj. No.: 113630.01.ZZ

SOIL BORING LOG

Project: DDMT GW Investigation
Drilling Contractor: Board Longyear\Minnesota
Drilling Method & Equipment: Rotasonic
Logger: S. Bruer\MGM

Elevation:
Location: Memphis, TN
Boring No. MW-54(J)
Start: 0840 2/9/96
Finish: 1950 2/9/96
Water Level:
Sheet 1 of 3

Depth Below Surface (FT)	Sample: Interval	Sample: Number and Type	Sample: Recovery (FT)	Standard Penetration Test Results 6"-6"-6" (N)	Soil Description: Soil name, uscs group symbol, color, moisture content, relative density or consistency, soil structure, mineralogy	Comments: Depth of casing, drilling rate, drilling fluid loss, tests and instrumentation
	0		5		1 inch TOPSOIL CLAYEY SILT (ML), light brown with light gray and black mottling, moist, soft, low plasticity, trace organics	Start Drilling at 0840 - using 6" core barrel modified loess
5	5					
10			8		- light brown, low to medium plasticity, no organics below 10 ft	
15	15				SILTY CLAY (CL), light brown with black mottling, moist, medium stiff, low to medium plasticity, trace iron nodules (< 1/8 inch diameter)	- gradational contact
			5			
20	20					
			5		- with black, orange, and light gray mottling below 21 ft	
25	25				- trace fine to coarse, quartz sand below 25 ft	- increasing sand content with depth below 25 ft Fluvial Deposits
30			8		SANDY CLAY (CL), light brown with black, light gray, and orange mottling, moist, stiff, medium plasticity, fine to medium, quartz sand	- gradational contact - orangish-brown below 29 ft - with brownish-red mottling below 31 ft
	33				CLAYEY SAND (SC), reddish-brown with light gray and light brown intermixing, moist, dense, fine to medium, quartz	- with fine to coarse, sub-rounded to rounded, chert gravel below 33 ft
35						

NOTES:

CH2MHILL

Proj. No.: 113630.01.ZZ

SOIL BORING LOG

Project: DDMT GW Investigation
Drilling Contractor: Boart Longyear\Minnesota
Drilling Method & Equipment: Rotasonic
Logger: S. Bruer\MGM

Depth Below Surface (FT)	Sample			Standard Penetration Test Results	Soil Description	Comments
	Interval	Number and Type	Recovery (FT)	6"-6"-6" (N)	Soil name, uscs group symbol, color, moisture content, relative density or consistency, soil structure, mineralogy	Depth of casing, drilling rate, drilling fluid loss, tests and instrumentation

Elevation:
Location: Memphis, TN
Boring No. MW-54(J)
Start: 0840 2/9/96
Finish: 1950 2/9/96
Water Level:
Sheet 2 of 3

			7		SILTY SAND (SM-SP), brownish-orange, moist, loose, fine to medium, quartz, with some fine to coarse, subrounded to rounded, chert gravel, micaceous	- gradational contact
40	40					
			4		42 ft - 43 ft: POORLY GRADED SAND (SP), tan, moist, medium, quartz	
	44					
45						
			6		- tan, medium to coarse below 46 ft - orangish-brown, with fine to coarse, subrounded to rounded, chert gravel below 48 ft	
50	50				- orangish-brown, fine to medium, no gravel below 49 ft	
			5		WELL GRADED GRAVELLY SAND (SW), yellowish-brown, moist, loose, fine to coarse, with fine to coarse, subrounded, chert gravel	- gradational contact - tan to yellowish-brown below 52 ft - free water present on gravels below 52 ft
55	55					
60			6			
					POORLY GRADED SAND (SP), yellowish-brown, moist, loose, fine to medium, quartz, trace coarse, quartz sand	- gradational contact - brownish-orange 63 ft to 63.5 ft
65	65					
			4		- trace fine to coarse, subrounded, chert gravel below 66 ft	
	69				WELL GRADED GRAVELLY SAND (SW), yellowish-brown, moist to wet, loose, fine to coarse, quartz with fine to coarse,	- gradational contact
70						

NOTES:

CH2M HILL

Proj. No.: 113630.01.ZZ

SOIL BORING LOG

Project: DDMT GW Investigation
Drilling Contractor: Boart Longyear\Minnesota
Drilling Method & Equipment: Rotasonic
Logger: S. Bruer\MGM

Elevation:
Location: Memphis, TN
Boring No. MW-54(J)
Start: 0840 2/9/96
Finish: 1950 2/9/96
Water Level:
Sheet 3 of 3

Depth Below Surface (FT)	Sample			Standard Penetration Test Results 6"-6"-6" (N)	Soil Description	Comments
	Interval	Number and Type	Recovery (FT)		Soil name, uscs group symbol, color, moisture content, relative density or consistency, soil structure, mineralogy	Depth of casing, drilling rate, drilling fluid loss, tests and instrumentation
	72		0		subangular to rounded, chert gravel	- no recovery 69 ft to 72 ft - changing to 4" core barrel
75	75		3		**POORLY GRADED SAND** (SP), yellowish-brown, moist, loose, fine to medium, quartz, trace coarse quartz/chert sand, micaceous	- gradational contact
80	81		4		- orangish-brown below 77 ft - yellowish-brown with trace fine, subrounded, chert gravel below 79 ft - wet below 81 ft	- 75 ft to 81 ft: hnu = 3 ppm (headspace in ziplock bag) - collected SBMW5477
85	89		8			
90 95	95		6		- trace coarse, quartz sand and fine to medium, subrounded, chert gravel below 91 ft	- collected Geotechnical Sample from 93 ft to 95 ft
100	100		5		**SILTY CLAY** (CL), light brown and light gray, moist, very stiff, medium plasticity - light gray and lignitic below 100 ft	- erosional contact Jackson Fm/Upper Claiborne
	101	S-1	1			Stopped Drilling at 1625
105					Boring Terminated at 101 Feet	MW-54 installed at 1950 - see attached construction diagram

NOTES:

DDMT MONITORING WELL INSTALLATION DIAGRAM (FLUSH MOUNT COMPLETION)

PROJECT NAME DDMT

PROJECT NO. 6301-04-0002

WELL NO. MW-155

WELL LOCATION West of MW-150

DATE 8/12/04

START TIME Start setting well at 11:00

GROUND SURFACE ELEVATION 291.84

TOP OF SCREEN ELEVATION 215.0

REFERENCE POINT ELEVATION 291.65

TYPE FILTER PACK SAND GRADATION 20/40

FILTER PACK MANUFACTURER FILTERSIL

SCREEN MATERIAL Schedule 40 PVC

MANUFACTURER Johnson Screens

SCREEN DIAMETER 2" SLOT SIZE .01"

RISER MATERIAL Schedule 40 PVC

MANUFACTURER Johnson Screens

RISER DIAMETER 2"

DRILLING TECHNIQUE RotoSonic

AUGER/BIT SIZE AND TYPE 6" outer core/4" inner core

REMARKS

BENTONITE TYPE 3/8" Coarse grade

MANUFACTURER Bariod

CEMENT TYPE Portland Cement Type I/II

MANUFACTURER LoneStar

BOREHOLE DIAMETER 6"

MACTEC FIELD REPRESENTATIVE Kevin Arnold

DRILLING CONTRACTOR ProSonic

AMOUNT BENTONITE BELOW (SCREEN) 2 bags (50lb)

AMOUNT BENTONITE USED (SEAL) 1 bag (50lb)

AMOUNT BENTONITE USED (GROUT) 0.75 bags (50lb)

DENSITY OF GROUT 13.9 lbs/kg

14.2 lbs/kg

14.6 lbs/kg

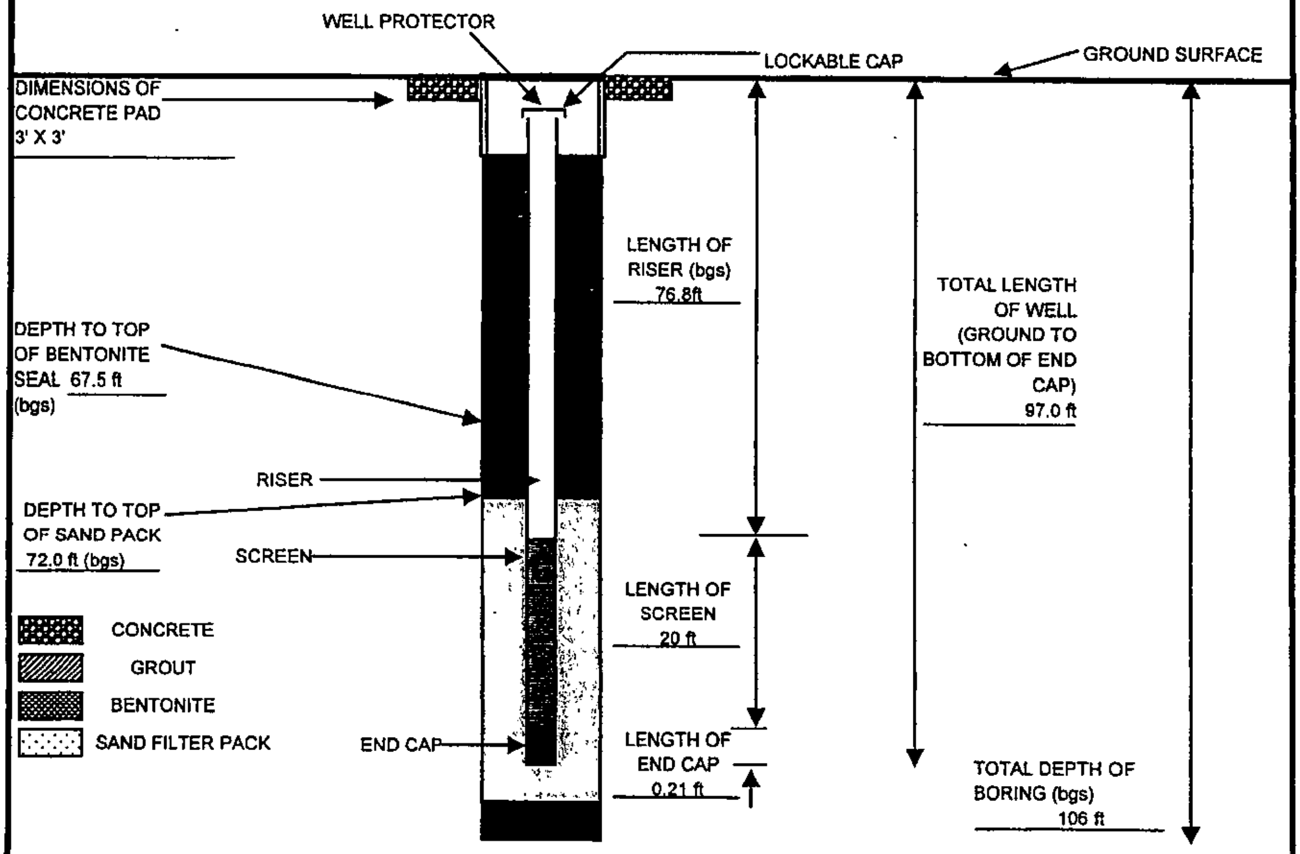
AMOUNT CEMENT USED (GROUT) 12 bags (94lb.)

AMOUNT SAND USED 9 bags (50lb)

STATIC WATER LEVEL (>24 hrs after dev) 75.48

MEASURED ON (Date/Time) 8/19/2004

(NOT TO SCALE: ALL MEASUREMENTS IN FEET)



DIMENSIONS OF CONCRETE PAD 3' X 3'

DEPTH TO TOP OF BENTONITE SEAL 67.5 ft (bgs)

DEPTH TO TOP OF SAND PACK 72.0 ft (bgs)

LENGTH OF RISER (bgs) 76.8ft

LENGTH OF SCREEN 20 ft

LENGTH OF END CAP 0.21 ft

TOTAL LENGTH OF WELL (GROUND TO BOTTOM OF END CAP) 97.0 ft

TOTAL DEPTH OF BORING (bgs) 106 ft

QA / QC

DRILLER: David Wilcox

INSPECTOR: Kevin Arnold

DISCREPANCIES:

CHECKED BY: RNQ

DATE. 9/13/04

812 67

MACTEC

MACTEC Engineering and Consulting
3200 Town Point Dr, Suite 100
Kennesaw, GA 30144

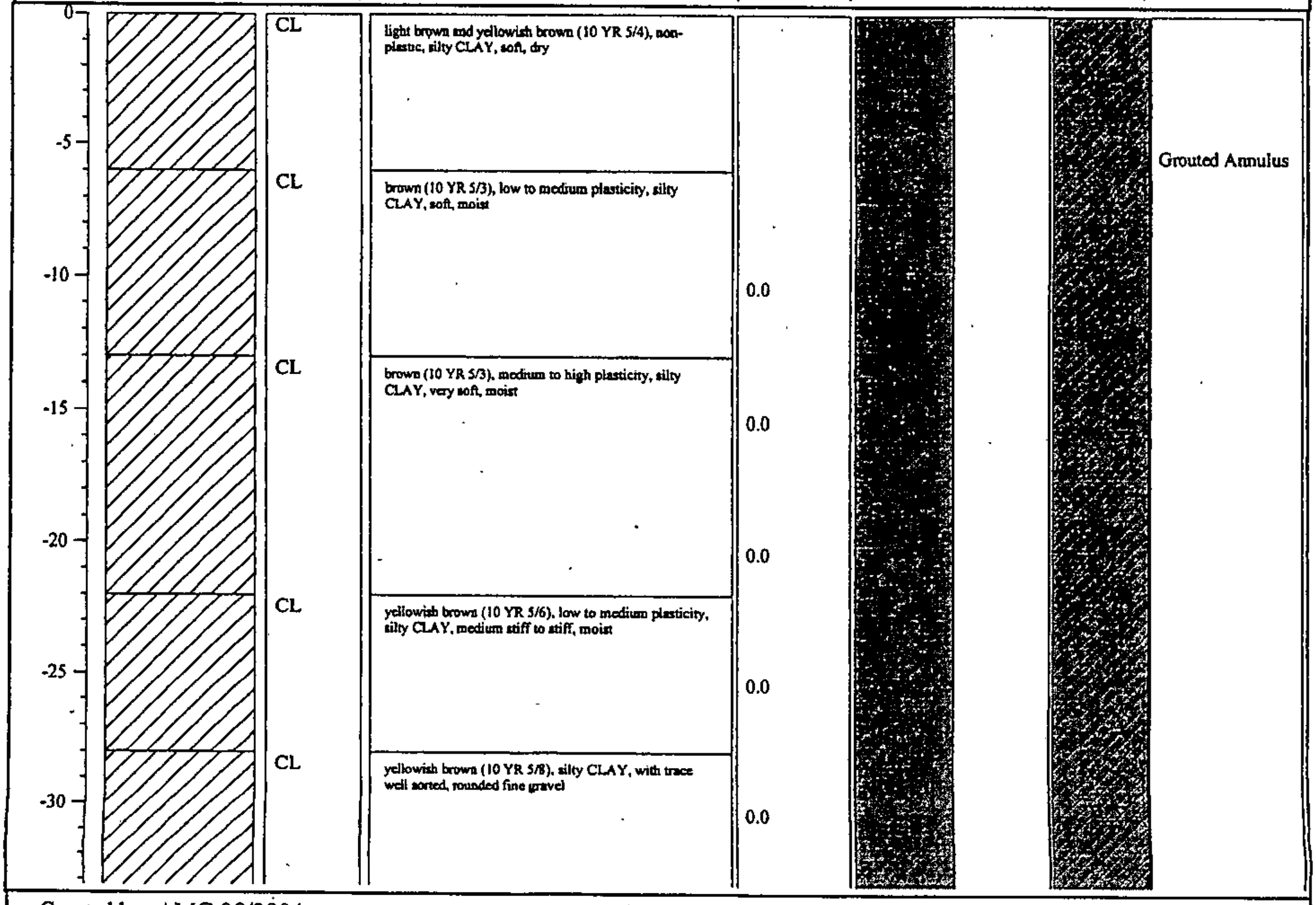
FIELD BOREHOLE LOG

BOREHOLE NO.: **MW-155**
TOTAL DEPTH: **106**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**DDMT**	DRILLING CO.:	**ProSonic**
SITE LOCATION:	**Memphis, TN**	DRILLER:	**David Wilcox**
JOB NO.:	**6301-04-0002**	RIG TYPE:	**RotoSonic**
LOGGED BY:	**Kevin Arnold**	TOP OF CASING ELEVATION:	**291.65'**
PROJECT MANAGER:	**Tom Holmes**	GROUND SURFACE ELEVATION:	**291.84'**
DATE DRILLED:	**8/12/04**		

NOTES:

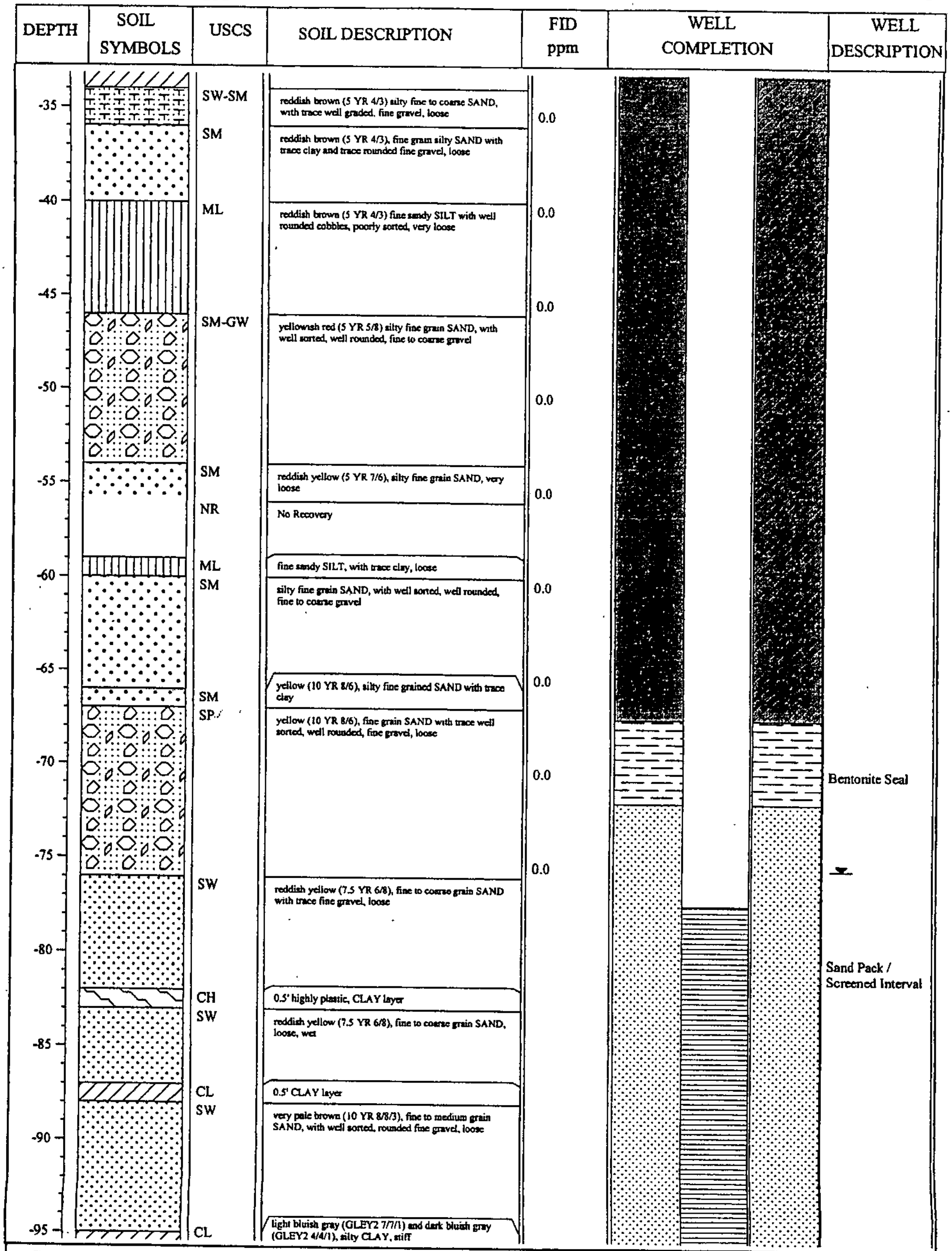
1) Drilling technique: 0 to 106.0 ft, bgs 6-inch diameter borehole with rotosonic.
2) Well construction: 2-inch diameter schedule 40 PVC casing set to 97.40 ft, bgs with 20 ft of 0.01-inch slot well screen.
3) Well screens the fluvial aquifer.
4) ▼ Stabilized water level measured on8/18/04



DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	FID ppm	WELL COMPLETION	WELL DESCRIPTION
	▨	CL	light brown and yellowish brown (10 YR 5/4), non-plastic, silty CLAY, soft, dry			Grouted Annulus
	▨	CL	brown (10 YR 5/3), low to medium plasticity, silty CLAY, soft, moist	0.0		
	▨	CL	brown (10 YR 5/3), medium to high plasticity, silty CLAY, very soft, moist	0.0 0.0		
	▨	CL	yellowish brown (10 YR 5/6), low to medium plasticity, silty CLAY, medium stiff to stiff, moist	0.0		
	▨	CL	yellowish brown (10 YR 5/8), silty CLAY, with trace well sorted, rounded fine gravel	0.0		

Created by: AMC 08/2004
Checked by: RNQ 9/2/04 RNQ

Borehole No. MW-155



USCS	SOIL DESCRIPTION	FID ppm
SW-SM	reddish brown (5 YR 4/3) silty fine to coarse SAND, with trace well graded, fine gravel, loose	0.0
SM	reddish brown (5 YR 4/3), fine gram silty SAND with trace clay and trace rounded fine gravel, loose	
ML	reddish brown (5 YR 4/3) fine sandy SILT with well rounded cobbles, poorly sorted, very loose	0.0 0.0
SM-GW	yellowish red (5 YR 5/8) silty fine grain SAND, with well sorted, well rounded, fine to coarse gravel	0.0
SM	reddish yellow (5 YR 7/6), silty fine grain SAND, very loose	0.0
NR	No Recovery	
ML	fine sandy SILT, with trace clay, loose	
SM	silty fine grain SAND, with well sorted, well rounded, fine to coarse gravel	0.0
SM	yellow (10 YR 8/6), silty fine grained SAND with trace clay	0.0
SP	yellow (10 YR 8/6), fine grain SAND with trace well sorted, well rounded, fine gravel, loose	0.0 0.0
SW	reddish yellow (7.5 YR 6/8), fine to coarse grain SAND with trace fine gravel, loose	
CH	0.5' highly plastic, CLAY layer	
SW	reddish yellow (7.5 YR 6/8), fine to coarse grain SAND, loose, wet	
CL	0.5' CLAY layer	
SW	very pale brown (10 YR 8/8/3), fine to medium grain SAND, with well sorted, rounded fine gravel, loose	
CL	light bluish gray (GLEY2 7/7/1) and dark bluish gray (GLEY2 4/4/1), silty CLAY, stiff	

Created by: AMC 08/2004
Checked by: RNQ 9/2/04

Borehole No. MW-155

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	FID ppm	WELL COMPLETION	WELL DESCRIPTION
-100 -105		CL	bluish black (GLEY2 2.5/1), medium plastic, CLAY, hard Boring Terminated at 106 feet bgs			Bentonite Plug

Created by: AMC 08/2004
Checked by: RNQ 9/2/04

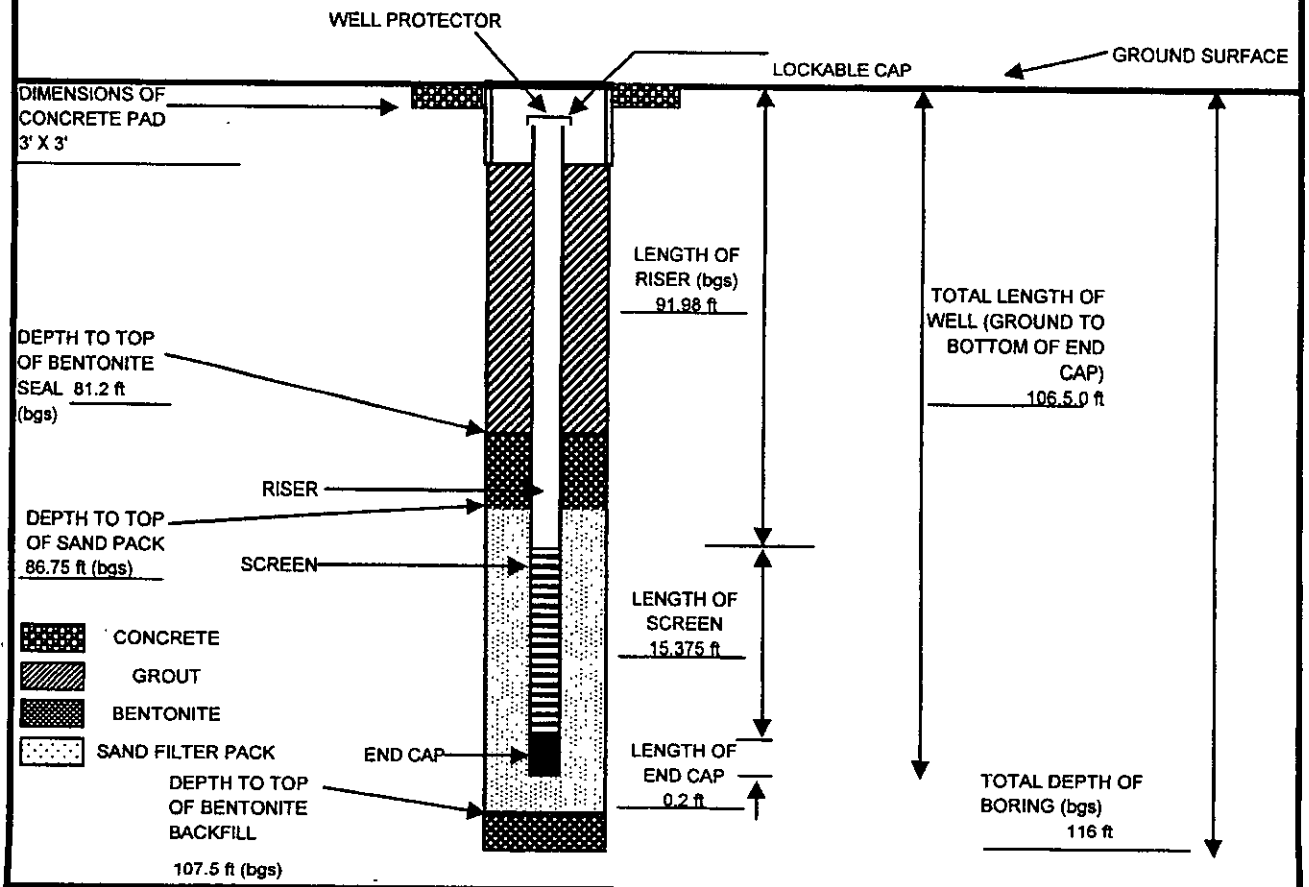
DDMT MONITORING WELL INSTALLATION DIAGRAM (FLUSH MOUNT COMPLETION)

PROJECT NAME DDMT
PROJECT NO. 6301-04-0019
WELL NO. MW-158
WELL LOCATION East of MW-152
DATE 10/04/04
START TIME 18:00 setting well

GROUND SURFACE ELEVATION
TOP OF SCREEN ELEVATION
REFERENCE POINT ELEVATION
TYPE FILTER PACK SAND GRADATION 20/40
FILTER PACK MANUFACTURER Unimin Corp.
SCREEN MATERIAL Schedule 40 PVC
MANUFACTURER Johnson Screens
SCREEN DIAMETER 2" SLOT SIZE .01"
RISER MATERIAL Schedule 40 PVC
MANUFACTURER Johnson Screens
RISER DIAMETER 2"
DRILLING TECHNIQUE RotoSonic
AUGER/BIT SIZE AND TYPE 6" outer core/4" inner core
REMARKS

BENTONITE TYPE 3/8" Coarse grade
MANUFACTURER Holeplug - Wyoming
CEMENT TYPE Portland Cement Type I/II
MANUFACTURER LoneStar
BOREHOLE DIAMETER 6"
MACTEC FIELD REPRESENTATIVE Kevin Arnold
DRILLING CONTRACTOR ProSonic
AMOUNT BENTONITE BELOW (SCREEN) 2 bags (50lb)
AMOUNT BENTONITE USED (SEAL) 1 bucket (50lb)
AMOUNT BENTONITE USED (GROUT) 1/2 5-gal bucket
DENSITY OF GROUT 13.6 lbs/kg
13.5 lbs/kg
14.4 lbs/kg
AMOUNT CEMENT USED (GROUT) 11 bags (94lb)
AMOUNT SAND USED 6.5 bags (50lb)
STATIC WATER LEVEL (>24 hrs after dev) 79.23
MEASURED ON (Date/Time) 10/5/2004 9:33

(NOT TO SCALE: ALL MEASUREMENTS IN FEET)



DIMENSIONS OF CONCRETE PAD 3' X 3'
DEPTH TO TOP OF BENTONITE SEAL 81.2 ft (bgs)
DEPTH TO TOP OF SAND PACK 86.75 ft (bgs)
DEPTH TO TOP OF BENTONITE BACKFILL 107.5 ft (bgs)
LENGTH OF RISER (bgs) 91.98 ft
LENGTH OF SCREEN 15.375 ft
LENGTH OF END CAP 0.2 ft
TOTAL LENGTH OF WELL (GROUND TO BOTTOM OF END CAP) 106.5.0 ft
TOTAL DEPTH OF BORING (bgs) 116 ft

QA / QC

DRILLER: David Wilcox
INSPECTOR: Kevin Arnold
DISCREPANCIES:
CHECKED BY: DATE:

MACTEC

MACTEC Engineering and Consulting
3200 Town Point Dr, Suite 100
Kennesaw, GA 30144

FIELD BOREHOLE LOG

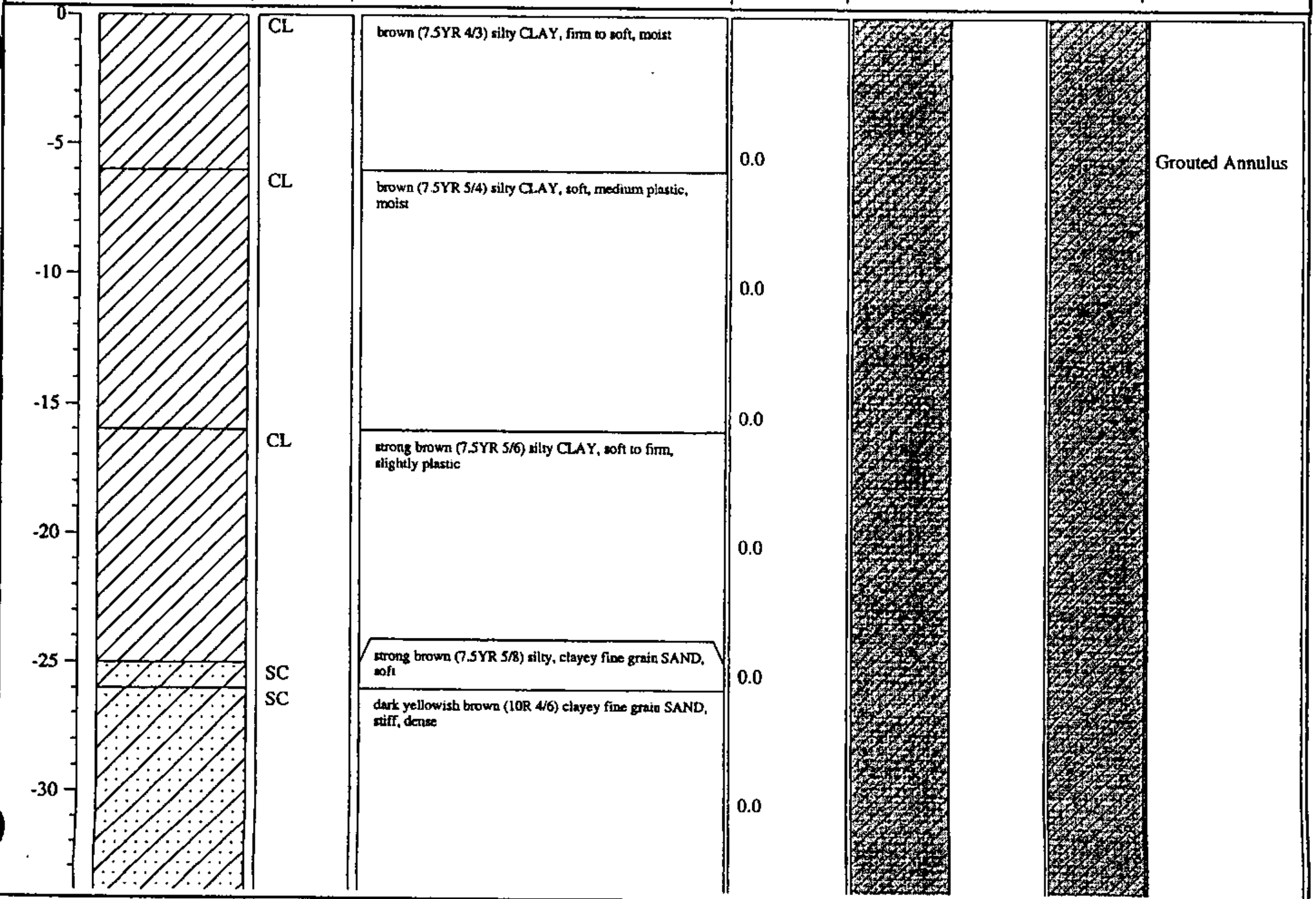
BOREHOLE NO.: **MW-158**

TOTAL DEPTH: **116'**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**DDMT**	DRILLING CO.:	**ProSonic**
SITE LOCATION:	**Memphis, TN**	DRILLER:	**David Wilcox**
JOB NO.:	**6301-04-0002**	RIG TYPE:	**RotoSonic**
LOGGED BY:	**Kevin Arnold**	TOP OF CASING ELEVATION:	
PROJECT MANAGER:	**Tom Holmes**	GROUND SURFACE ELEVATION:	**294.2**
DATE DRILLED:	**10/4/04**		

NOTES:

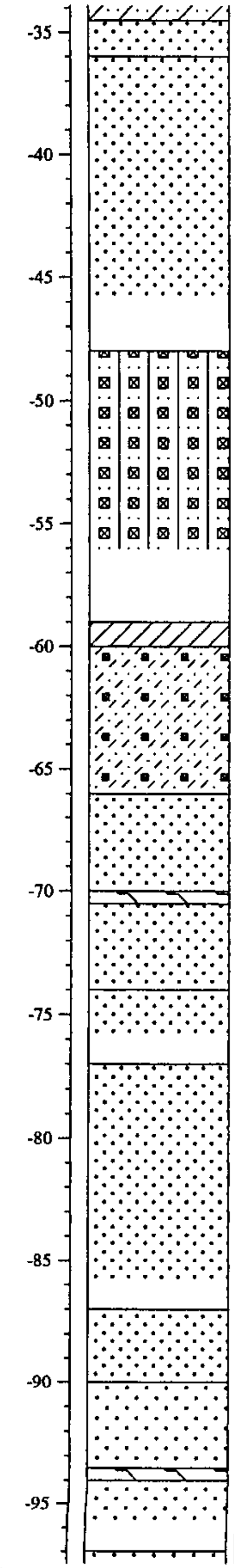
1) Drilling technique: 0 to 116 ft, bgs 6-inch diameter borehole with rotosonic.
2) Well construction: 2-inch diameter schedule 40 PVC casing set to 106.5ft, bgs with 20 ft of 0.01-inch slot well screen.
3) Well screens the fluvial aquifer.
4) ▼ Stabilized water level measured on 10/15/04



DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	FID ppm	WELL COMPLETION	WELL DESCRIPTION
0 -5		CL	brown (7.5YR 4/3) silty CLAY, firm to soft, moist	0.0		Grouted Annulus
-10 -15		CL	brown (7.5YR 5/4) silty CLAY, soft, medium plastic, moist	0.0 0.0		
-20		CL	strong brown (7.5YR 5/6) silty CLAY, soft to firm, slightly plastic	0.0		
-25		SC	strong brown (7.5YR 5/8) silty, clayey fine grain SAND, soft	0.0		
-30		SC	dark yellowish brown (10R 4/6) clayey fine grain SAND, stiff, dense	0.0		

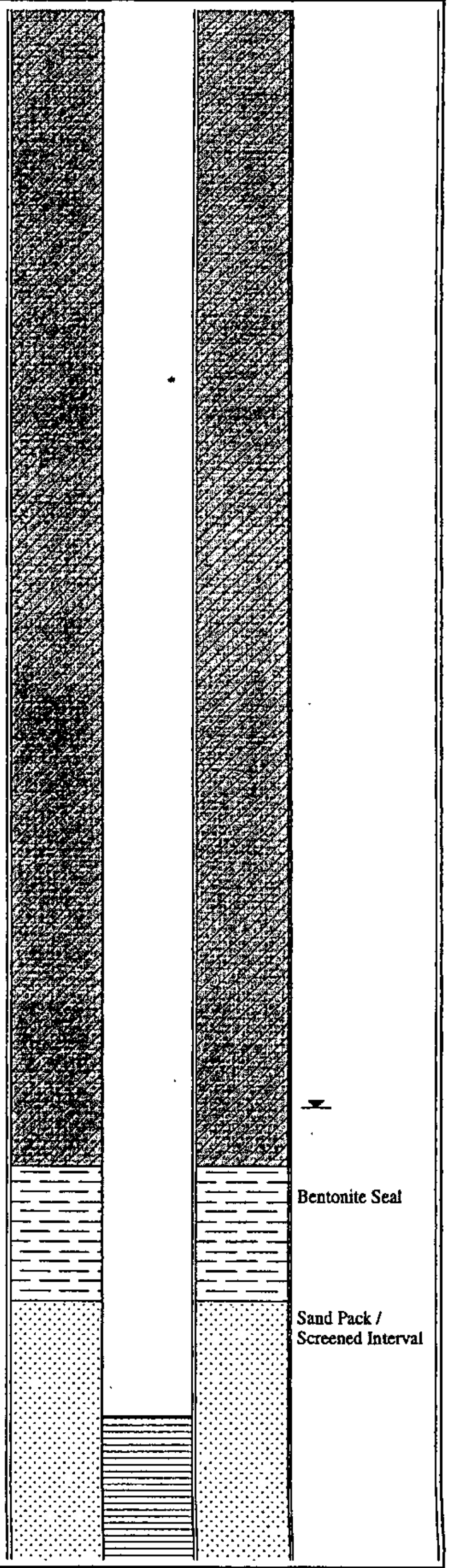
Created by: JLP 10/18/04
Checked by:

Borehole No. **MW-158**



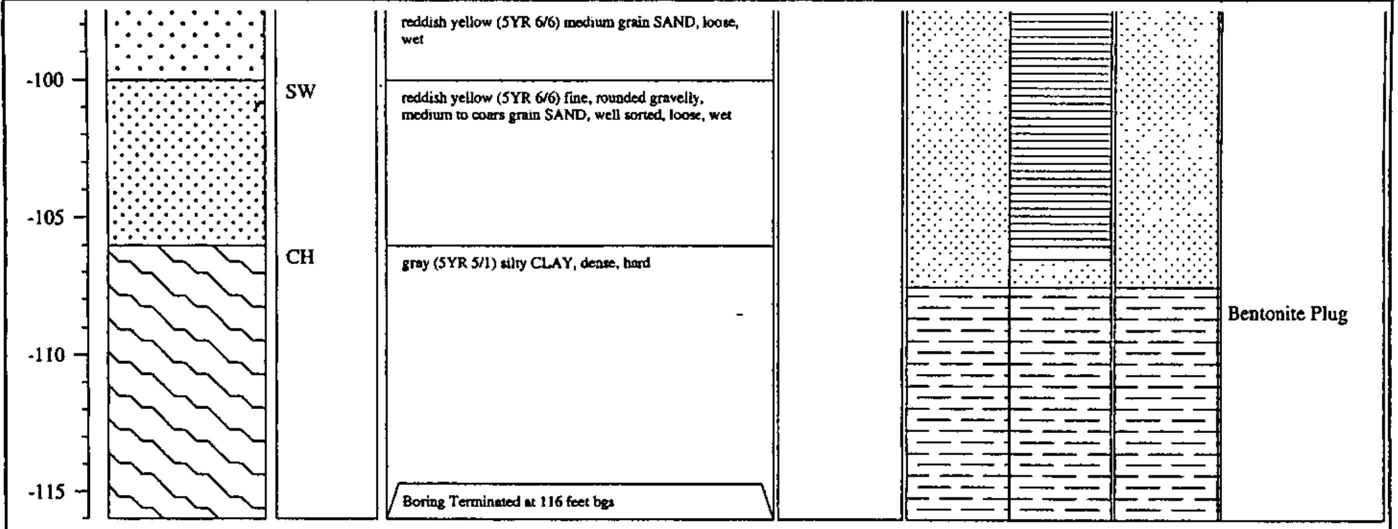
USCS	SOIL DESCRIPTION
SP	red (2.5YR 4/6) slightly clayey fine grain SAND, with some rounded, coarse gravel, medium dense
SP	red (2.5YR 5/6) fine to coarse, rounded gravelly, fine grain SAND, poorly sorted, loose
NR	No Recovery
GM	red (2.5YR 5/6) and reddish brown (5YR 5/4) fine grain sandy, fine to coarse, rounded to subrounded GRAVEL, well sorted, some cobbles
NR	No Recovery
CL	CLAY
GC	reddish yellow (7.5YR 6/6) fine grain SAND, with some well sorted, rounded to subrounded coarse gravel, some cobbles, loose
SP	reddish yellow (5YR 6/8) fine grain SAND, some rounded coarse gravel, trace cobbles, loose, poorly sorted
CH	CLAY, highly plastic, wet
SP	reddish yellow (5YR 6/8) fine grain SAND, some rounded coarse gravel, trace cobbles, loose, poorly sorted
SP	reddish yellow (5YR 6/6) fine grain SAND, with some well sorted, rounded coarse gravel, loose to very loose, wet
NR	No Recovery
SP	reddish yellow (5YR 6/6) well rounded, well sorted, coarse gravelly (10%), medium grain SAND, wet, loose
NR	No Recovery
SP	reddish yellow (5YR 6/6) well rounded, well sorted, coarse gravelly (10%), medium grain SAND, wet, loose
SM	reddish yellow (5YR 6/6) medium grain SAND, loose, wet
CH	CLAY, highly plastic, wet
SM	reddish yellow (5YR 6/6) medium grain SAND, loose, wet
NR SM	No Recovery

DEPTH	FID ppm
-35	0 0
-40	0.0
-45	0.0
-50	0.0
-55	0.0
-60	0.0
-65	0.0
-70	0.0



Created by: JLP 10/18/04
Checked by:

Borehole No. **MW-158**



DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	FID ppm	WELL COMPLETION	WELL DESCRIPTION
			reddish yellow (5YR 6/6) medium grain SAND, loose, wet			
-100		SW	reddish yellow (5YR 6/6) fine, rounded gravelly, medium to coars grain SAND, well sorted, loose, wet			
-105		CH	gray (5YR 5/1) silty CLAY, dense, hard			Bentonite Plug
-110						
-115			Boring Terminated at 116 feet bgs			

Created by: JLP 10/18/04
Checked by:

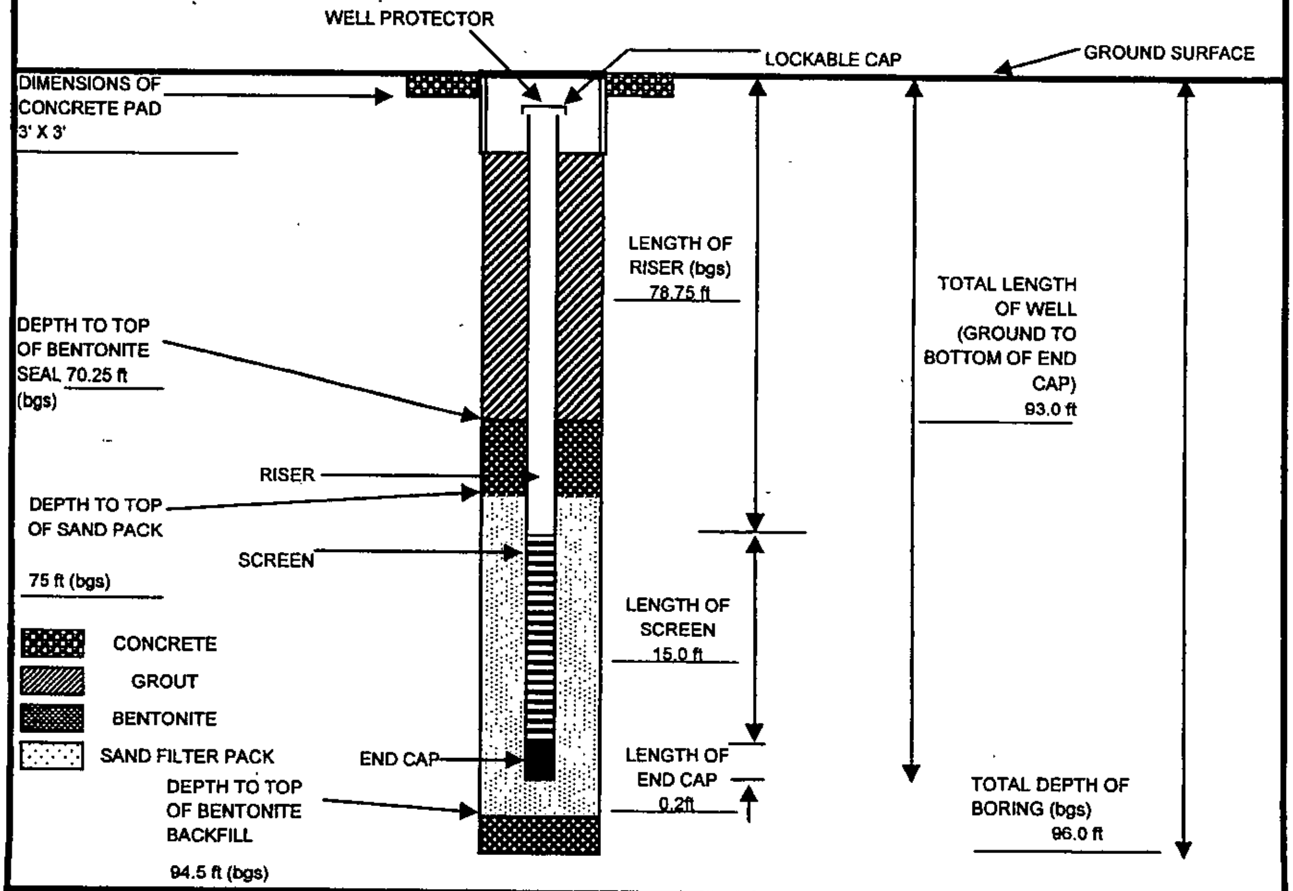
DDMT MONITORING WELL INSTALLATION DIAGRAM (FLUSH MOUNT COMPLETION)

PROJECT NAME DDMT
PROJECT NO. 6301-04-0019
WELL NO. MW-158A
WELL LOCATION North 10 feet of MW-158
DATE 10/05/04
START TIME Start grouting at 14:45

GROUND SURFACE ELEVATION
TOP OF SCREEN ELEVATION
REFERENCE POINT ELEVATION
TYPE FILTER PACK SAND GRADATION 20/40
FILTER PACK MANUFACTURER FILTERSIL
SCREEN MATERIAL Schedule 40 PVC
MANUFACTURER Johnson Screens
SCREEN DIAMETER 2" SLOT SIZE .01"
RISER MATERIAL Schedule 40 PVC
MANUFACTURER Johnson Screens
RISER DIAMETER 2"
DRILLING TECHNIQUE RotoSonic
AUGER/BIT SIZE AND TYPE 6" outer core/4" inner core
REMARKS

BENTONITE TYPE 3/8" Coarse grade
MANUFACTURER Holeplug-Wyoming
CEMENT TYPE Portland Cement Type I/II
MANUFACTURER LoneStar
BOREHOLE DIAMETER 6"
MACTEC FIELD REPRESENTATIVE Kevin Arnold
DRILLING CONTRACTOR ProSonic
AMOUNT BENTONITE BELOW (SCREEN) .5 bags (50lb)
AMOUNT BENTONITE USED (SEAL) 1 bucket
AMOUNT GEL-X USED (GROUT) 0.75 bucket
DENSITY OF GROUT 13.5 lbs/kg
13.6 lbs/kg
AMOUNT CEMENT USED (GROUT) 8 bags (94lb)
AMOUNT SAND USED 7.5 bags (50lb)
STATIC WATER LEVEL (>24 hrs after dev) 79.19
MEASURED ON (Date/Time) 10/06/04 / 8:48

(NOT TO SCALE: ALL MEASUREMENTS IN FEET)



DIMENSIONS OF CONCRETE PAD 3' X 3'
DEPTH TO TOP OF BENTONITE SEAL 70.25 ft (bgs)
DEPTH TO TOP OF SAND PACK 75 ft (bgs)
DEPTH TO TOP OF BENTONITE BACKFILL 94.5 ft (bgs)
LENGTH OF RISER (bgs) 78.75 ft
LENGTH OF SCREEN 15.0 ft
LENGTH OF END CAP 0.2ft
TOTAL LENGTH OF WELL (GROUND TO BOTTOM OF END CAP) 93.0 ft
TOTAL DEPTH OF BORING (bgs) 96.0 ft

QA / QC

DRILLER: David Wilcox
INSPECTOR: Kevin Arnold
DISCREPANCIES:
CHECKED BY:
DATE:

MACTEC

MACTEC Engineering and Consulting
3200 Town Point Dr, Suite 100
Kennesaw, GA 30144

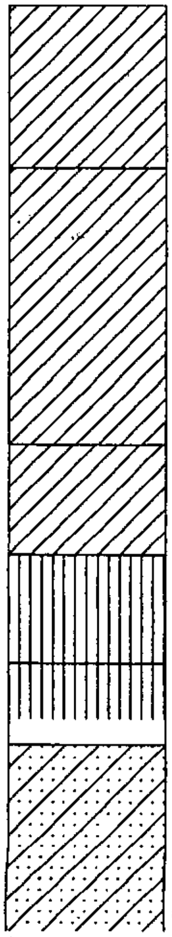
FIELD BOREHOLE LOG

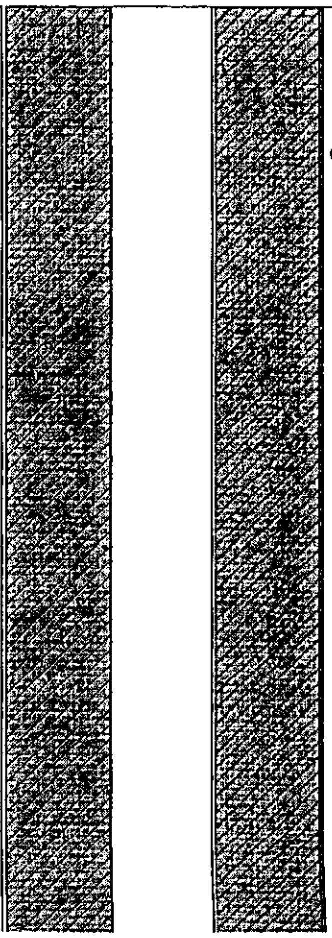
BOREHOLE NO.: **MW-158A**
TOTAL DEPTH: **96'**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**DDMT**	DRILLING CO.:	**ProSonic**
SITE LOCATION:	**Memphis, TN**	DRILLER:	**David Wilcox**
JOB NO.:	**6301-04-0002**	RIG TYPE:	**RotoSonic**
LOGGED BY:	**Kevin Arnold**	TOP OF CASING ELEVATION:	
PROJECT MANAGER:	**Tom Holmes**	GROUND SURFACE ELEVATION:	**294.2**
DATE DRILLED:	**10/5/04**		

NOTES:

1) Drilling technique: 0 to 96 ft, bgs 6-inch diameter borehole with rotosonic.
2) Well construction: 2-inch diameter schedule 40 PVC casing set to 93 ft, bgs with 20 ft of 0.01-inch slot well screen.
3) Well screens the fluvial aquifer.
4) ▼ Stabilized water level measured on 10/15/04

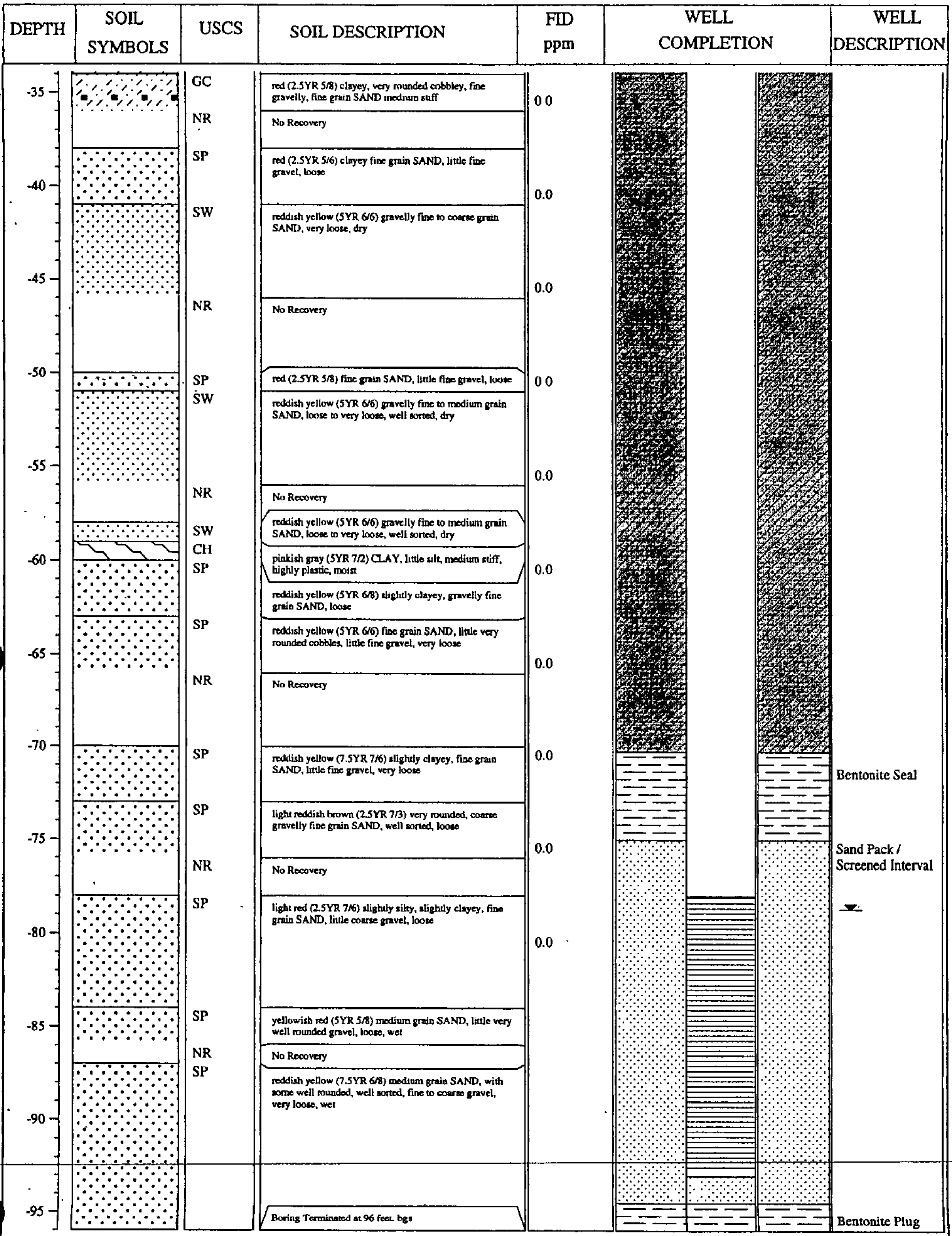




DEPTH	USCS	SOIL DESCRIPTION	FID ppm	WELL DESCRIPTION
0	CL	brown (7.5YR 5/4) non-plastic silty CLAY, soft, medium stiff	0.0	
-5			0.0	Grouted Annulus
	CL	reddish brown (5YR 5/4) silty CLAY, soft, medium plasticity, moist		
-10			0.0	
-15			0.0	
	CL	reddish brown (5YR 5/4) silty CLAY, little plasticity, medium stiff, very little moisture		
-20	ML	reddish brown (5YR 4/4) clayey SILT, soft to medium stiff, dry	0.0	
	ML	yellowish red (5YR 5/6) clayey SILT, soft to medium stiff, little plasticity, little moisture		
-25			0.0	
	NR	No Recovery		
	SC	red (2.5YR 5/8) clayey fine grain SAND, tight, dense, medium stiff		
-30			0.0	

Created by: JLP 10/18/04
Checked by:

Borehole No. MW-158A



DEPTH	USCS	SOIL DESCRIPTION	FID ppm	WELL DESCRIPTION
-35	GC	red (2.5YR 5/8) clayey, very rounded cobbley, fine gravelly, fine grain SAND medium suff	0 0	
	NR	No Recovery		
-40	SP	red (2.5YR 5/6) clayey fine grain SAND, little fine gravel, loose	0.0	
-45	SW	reddish yellow (5YR 6/6) gravelly fine to coarse grain SAND, very loose, dry	0.0	
	NR	No Recovery		
-50	SP	red (2.5YR 5/8) fine grain SAND, little fine gravel, loose	0 0	
-55	SW	reddish yellow (5YR 6/6) gravelly fine to medium grain SAND, loose to very loose, well sorted, dry	0.0	
	NR	No Recovery		
	SW	reddish yellow (5YR 6/6) gravelly fine to medium grain SAND, loose to very loose, well sorted, dry		
	CH	pinkish gray (5YR 7/2) CLAY, little silt, medium stiff, highly plastic, moist		
-60	SP	reddish yellow (5YR 6/8) slightly clayey, gravelly fine grain SAND, loose	0.0	
-65	SP	reddish yellow (5YR 6/6) fine grain SAND, little very rounded cobbles, little fine gravel, very loose	0.0	
	NR	No Recovery		
-70	SP	reddish yellow (7.5YR 7/6) slightly clayey, fine grain SAND, little fine gravel, very loose	0.0	Bentonite Seal
-75	SP	light reddish brown (2.5YR 7/3) very rounded, coarse gravelly fine grain SAND, well sorted, loose	0.0	Sand Pack / Screened Interval
	NR	No Recovery		
-80	SP	light red (2.5YR 7/6) slightly silty, slightly clayey, fine grain SAND, little coarse gravel, loose	0.0	▼
-85	SP	yellowish red (5YR 5/8) medium grain SAND, little very well rounded gravel, loose, wet		
	NR	No Recovery		
-90 -95	SP	reddish yellow (7.5YR 6/8) medium grain SAND, with some well rounded, well sorted, fine to coarse gravel, very loose, wet Boring Terminated at 96 feet. bgs		Bentonite Plug

Created by: JLP 10/18/04
Checked by:

DDMT MONITORING WELL INSTALLATION DIAGRAM (FLUSH MOUNT COMPLETION)

PROJECT NAME DDMT
WELL NO. MW-159
DATE 10/06/04

PROJECT NO. 6301-04-0019
WELL LOCATION North of MW-149
START TIME 15:20 begin installing well

GROUND SURFACE ELEVATION
TOP OF SCREEN ELEVATION
REFERENCE POINT ELEVATION

TYPE FILTER PACK SAND GRADATION 20/40
FILTER PACK MANUFACTURER FILTERSIL

SCREEN MATERIAL Schedule 40 PVC
MANUFACTURER Johnson Screens
SCREEN DIAMETER 2" SLOT SIZE .01"

RISER MATERIAL Schedule 40 PVC
MANUFACTURER Johnson Screens
RISER DIAMETER 2"
DRILLING TECHNIQUE RotoSonic
AUGER/BIT SIZE AND TYPE 6" outer core/4" inner core

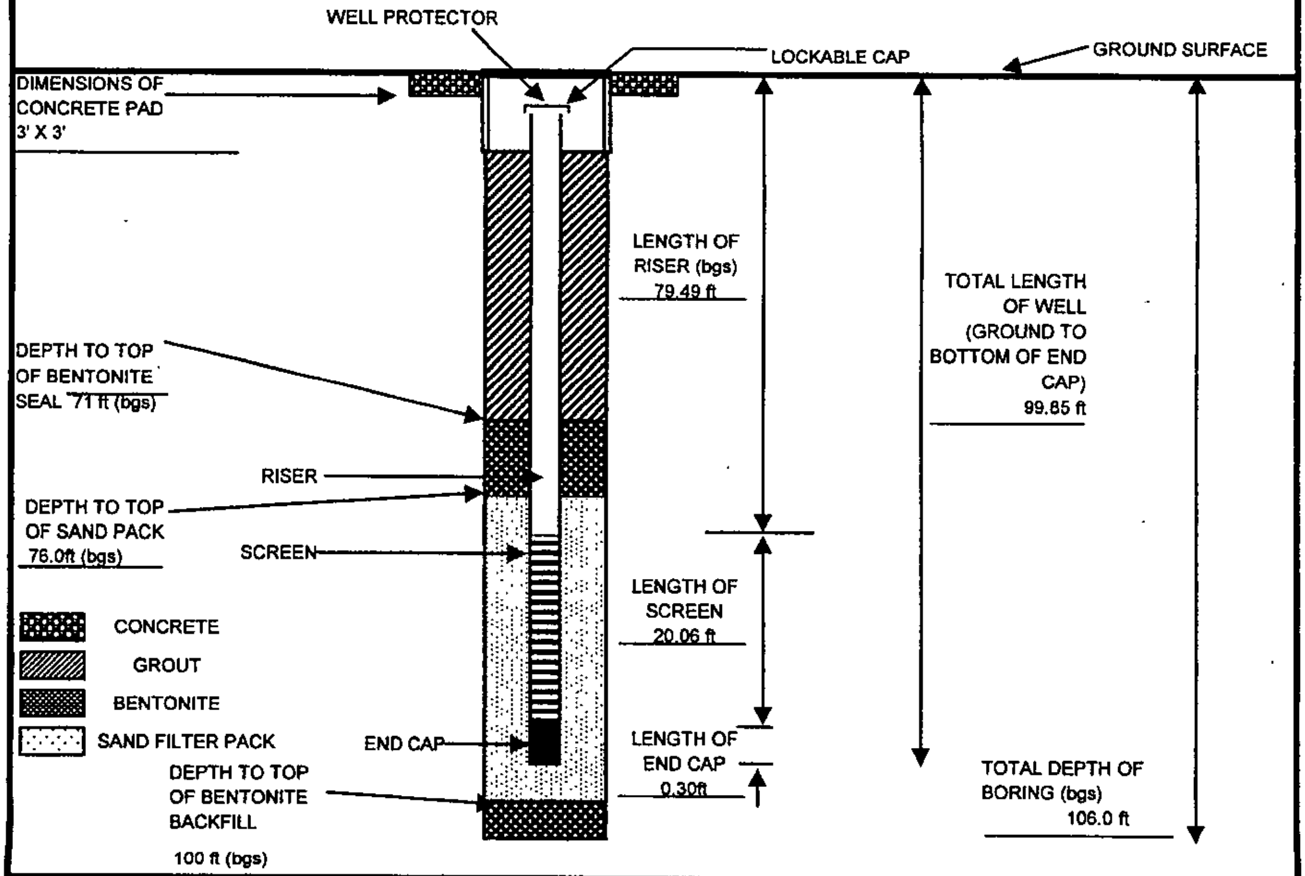
REMARKS

BENTONITE TYPE 3/8" Coarse grade
MANUFACTURER Holeplug - Wyoming
CEMENT TYPE Portland Cement Type I/II
MANUFACTURER LoneStar
BOREHOLE DIAMETER 6"
MACTEC FIELD REPRESENTATIVE Kevin Arnold
DRILLING CONTRACTOR ProSonic
AMOUNT BENTONITE BELOW (SCREEN) 1.25 bags (50lb)
AMOUNT BENTONITE USED (SEAL) 1 bucket (50lb)
AMOUNT BENTONITE USED (GROUT) 1/5 bucket
DENSITY OF GROUT 13.5 lbs/kg
13.5 lbs/kg

AMOUNT CEMENT USED (GROUT) 8 bags (94lb)
AMOUNT SAND USED 13 bags (50lb)

STATIC WATER LEVEL (>24 hrs after dev) 70.76
MEASURED ON (Date/Time) 10/7/2004 1015

(NOT TO SCALE: ALL MEASUREMENTS IN FEET)



DIMENSIONS OF CONCRETE PAD 3' X 3'
LENGTH OF RISER (bgs) 79.49 ft
TOTAL LENGTH OF WELL (GROUND TO BOTTOM OF END CAP) 99.85 ft
DEPTH TO TOP OF BENTONITE SEAL 71 ft (bgs)
DEPTH TO TOP OF SAND PACK 76.0ft (bgs)
LENGTH OF SCREEN 20.06 ft
LENGTH OF END CAP 0.30ft
DEPTH TO TOP OF BENTONITE BACKFILL 100 ft (bgs)
TOTAL DEPTH OF BORING (bgs) 106.0 ft

QA / QC

DRILLER: David Wilcox
INSPECTOR: Kevin Arnold
DISCREPANCIES:
CHECKED BY:
DATE:

MACTEC

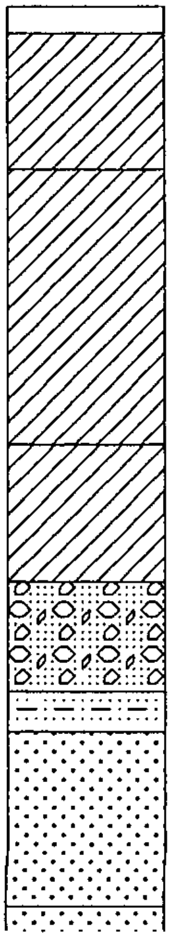
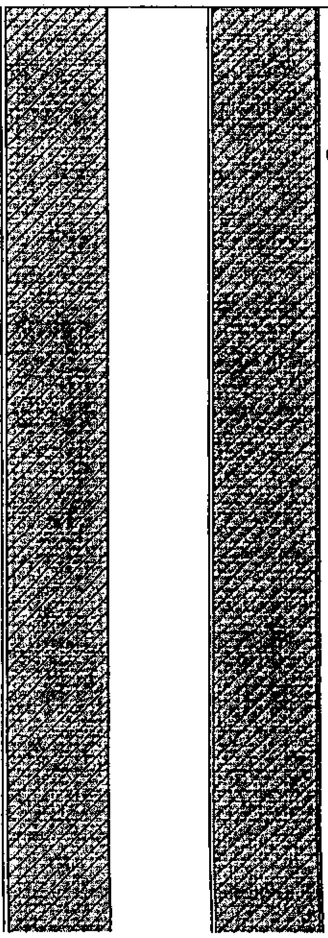
MACTEC Engineering and Consulting
3200 Town Point Dr, Suite 100
Kennesaw, GA 30144

FIELD BOREHOLE LOG

BOREHOLE NO.: **MW-159**
TOTAL DEPTH: **106'**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**DDMT**	DRILLING CO.:	**ProSonic**
SITE LOCATION:	**Memphis, TN**	DRILLER:	**David Wilcox**
JOB NO.:	**6301-04-0019**	RIG TYPE:	**RotoSonic**
LOGGED BY:	**Kevin Arnold**	TOP OF CASING ELEVATION:	
PROJECT MANAGER:	**Tom Holmes**	GROUND SURFACE ELEVATION:	**287.3**
DATE DRILLED:	**10-6-04**		

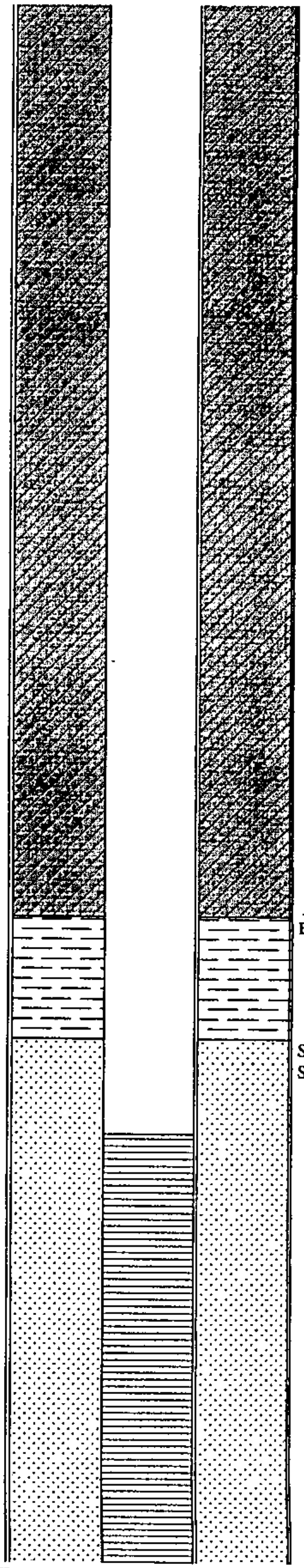
NOTES:
1) Drilling technique: 0 to 106 ft, bgs 6-inch diameter borehole with rotosonic.
2) Well construction: 2-inch diameter schedule 40 PVC casing set to 99.85ft, bgs with 20 ft of 0.01-inch slot well screen.
3) Well screens the fluvial aquifer.
4) ▼ Stabilized water level measured on 10/15/04

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	FID ppm	WELL COMPLETION	WELL DESCRIPTION
0		NR	No Recovery			
		CL	dark yellowish brown (10YR 4/6) silty CLAY, soft, slightly plastic			
-5				0.0		Grouted Annulus
		CL	dark yellowish brown (10YR 4/4) silty CLAY, soft to medium stiff, medium plastic, moist			
-10				0.0		
-15				0.0		
		CL	yellowish brown (10YR 5/8) silty CLAY, medium stiff to stiff, medium plastic			
-20				0.0		
		GW-CL	yellowish brown (10YR 5/8) well rounded, well sorted GRAVEL and silty CLAY, some cobbles, medium stiff, slightly plastic			
-25		SP-SC	yellowish red (5YR 5/6) fine to coarse gravelly, clayey fine grain SAND, medium stiff	0.0		
		NR	No Recovery			
		SP	red (2.5YR 5/8) slightly clayey, fine, rounded to subrounded gravelly, fine grain SAND, loose			
-30				0.0		
		SP	red (2.5YR 5/8) slightly fine gravelly, fine grain SAND,			

Created by: JLP 10/18/04
Checked by:

Borehole No. **MW-159**

812 79

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	FID ppm	WELL COMPLETION	WELL DESCRIPTION
-35			with some medium grain sand, loose	0.0		
		NR	No Recovery			
-40		GC	red (5YR 5/8) slightly clayey, fine GRAVEL, loose	0.0		
-45		SP	light reddish brown (5YR 6/4) fine to coarse gravelly, fine grain SAND, loose, with some very rounded to subrounded cobbles	0.0		
		NR	No Recovery			
-50		SP	pink (5YR 7/3) and reddish yellow (5YR 6/6) fine to coarse, well sorted, rounded to subrounded gravelly, slightly clayey, fine grain SAND, loose	0.0		
-55		SM	pink (5YR 7/3) fine grain SAND, very loose	0.0		
		NR	No Recovery			
-60		SM	light red (2.5YR 6/8) slightly medium grain sand and fine grain SAND, loose	0:0		
-65		SM	pink (5YR 7/4) slightly medium grain sand and fine grain SAND, well sorted, loose	0.0		
-70		NR	No Recovery	0.0		
		SM	pink (5YR 7/4) slightly medium grain sand and fine grain SAND, well sorted, loose			Bentonite Seal
-75		SP	yellowish red (5YR 5/8) fine gravelly, fine grain SAND, well sorted, loose, wet			
		NR	No Recovery			Sand Pack / Screened Interval
-80		SP	yellowish red (5YR 5/8) fine gravelly, fine grain SAND, well sorted, loose, wet			
		CH	pinkish gray (5YR 6/2) CLAY, medium stiff, highly plastic			
-85		SP	yellowish red (5YR 5/8) fine gravelly, fine grain SAND, well sorted, loose, wet			
		NR	No Recovery			
-90 -95		SP	yellowish red (5YR 5/8) fine gravelly, fine grain SAND, well sorted, loose, wet			
		CH	bluish black (GLEY 2/2.5 5PB) silty CLAY, hard			

Created by: JLP 10/18/04
Checked by:

Borehole No. **MW-159**

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	FID ppm	WELL COMPLETION	WELL DESCRIPTION
		ML	bluish black (GLEY 2/2.5/1) clayey SILT, loose			
-100		CH	bluish black (GLEY 2/2.5/1) silty CLAY, dense, hard			Bentonite Plug
-105			Boring Terminated at 106 feet bgs			

Created by: JLP 10/18/04
Checked by:

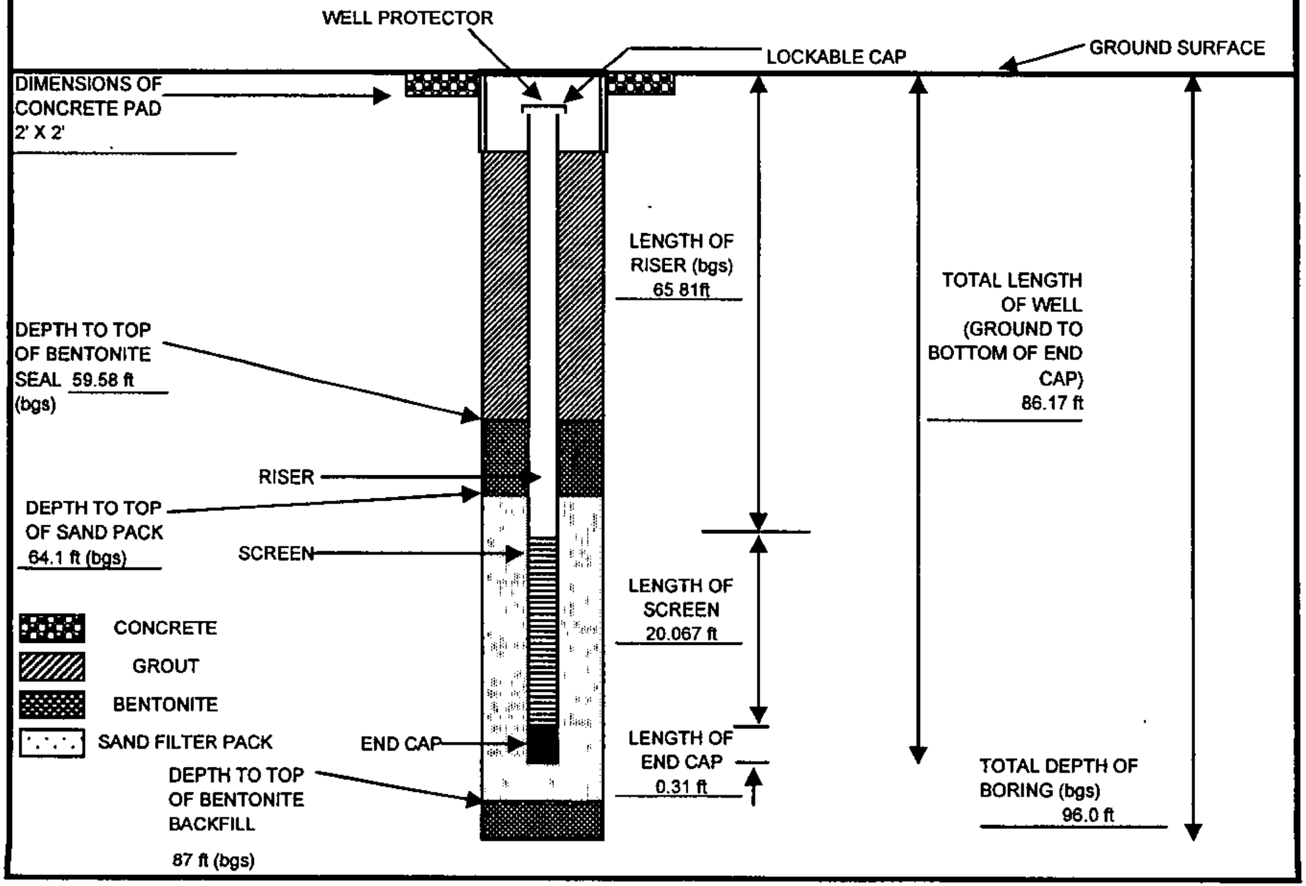
DDMT MONITORING WELL INSTALLATION DIAGRAM (FLUSH MOUNT COMPLETION)

PROJECT NAME DDMT
PROJECT NO. 6301-04-0019
WELL NO. MW-160
WELL LOCATION Northwest of MW-150
DATE 10/11/04
START TIME 12:45

GROUND SURFACE ELEVATION 294.11
TOP OF SCREEN ELEVATION 228.19
REFERENCE POINT ELEVATION 294.00
TYPE FILTER PACK SAND GRADATION 20/40
FILTER PACK MANUFACTURER FILTERSIL
SCREEN MATERIAL Schedule 40 PVC
MANUFACTURER Johnson Screens
SCREEN DIAMETER 2" SLOT SIZE .01"
RISER MATERIAL Schedule 40 PVC
MANUFACTURER Johnson Screens
RISER DIAMETER 2"
DRILLING TECHNIQUE RotoSonic
AUGER/BIT SIZE AND TYPE 6" outer core/4" inner core
REMARKS

BENTONITE TYPE 3/8" Coarse grade
MANUFACTURER Cetco / Arlington Heights, IL
CEMENT TYPE Portland Cement Type I/II
MANUFACTURER LoneStar
BOREHOLE DIAMETER 6"
MACTEC FIELD REPRESENTATIVE Kevin Arnold
DRILLING CONTRACTOR ProSonic
AMOUNT BENTONITE BELOW (SCREEN) 2 5 gallon buckets
AMOUNT BENTONITE USED (SEAL) 1 5 gallon bucket
AMOUNT BENTONITE USED (GROUT)
DENSITY OF GROUT 13.5 lbs/kg
14.0 lbs/kg
AMOUNT CEMENT USED (GROUT)
AMOUNT SAND USED 9 bags (50lb)
STATIC WATER LEVEL (>24 hrs after dev) 77.81
MEASURED ON (Date/Time) 10/11/2004 1110

(NOT TO SCALE: ALL MEASUREMENTS IN FEET)



QA / QC

DRILLER: David Wilcox
INSPECTOR: Kevin Arnold
DISCREPANCIES:
CHECKED BY:
DATE:

MACTEC

MACTEC Engineering and Consulting
3200 Town Point Dr, Suite 100
Kennesaw, GA 30144

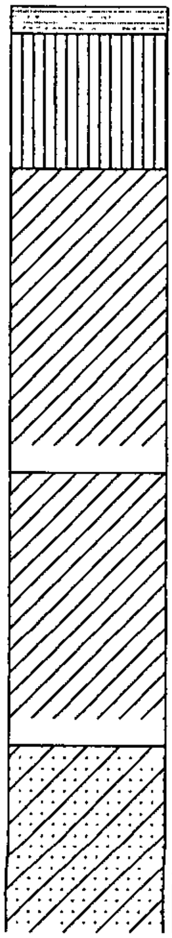
FIELD BOREHOLE LOG

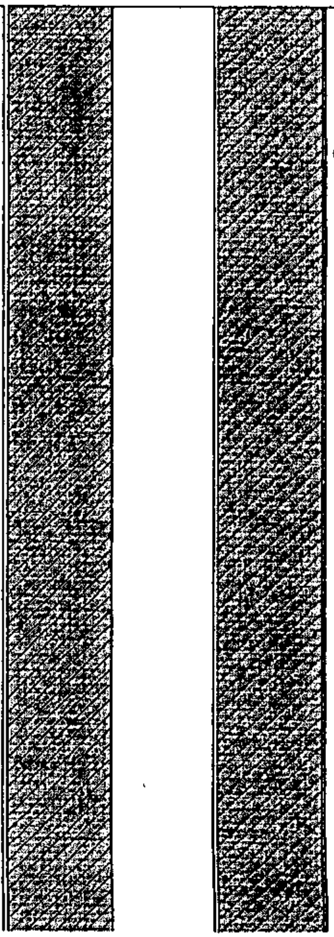
BOREHOLE NO.: **MW-160**
TOTAL DEPTH: **96'**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**DDMT**	DRILLING CO.:	**ProSonic**
SITE LOCATION:	**Memphis, TN**	DRILLER:	**David Wilcox**
JOB NO.:	**6301-04-0019**	RIG TYPE:	**RotoSonic**
LOGGED BY:	**Kevin**	TOP OF CASING ELEVATION:	
PROJECT MANAGER:	**Tom Holmes**	GROUND SURFACE ELEVATION:	**294**
DATE DRILLED:	**10/11/04**		

NOTES:

1) Drilling technique: 0 to 96 ft, bgs 6-inch diameter borehole with rotosonic.
2) Well construction: 2-inch diameter schedule 40 PVC casing set to 86.17ft, bgs with 20 ft of 0.01-inch slot well screen.
3) Well screens the fluvial aquifer.
4) ▼ Stabilized water level measured on 10/15/04

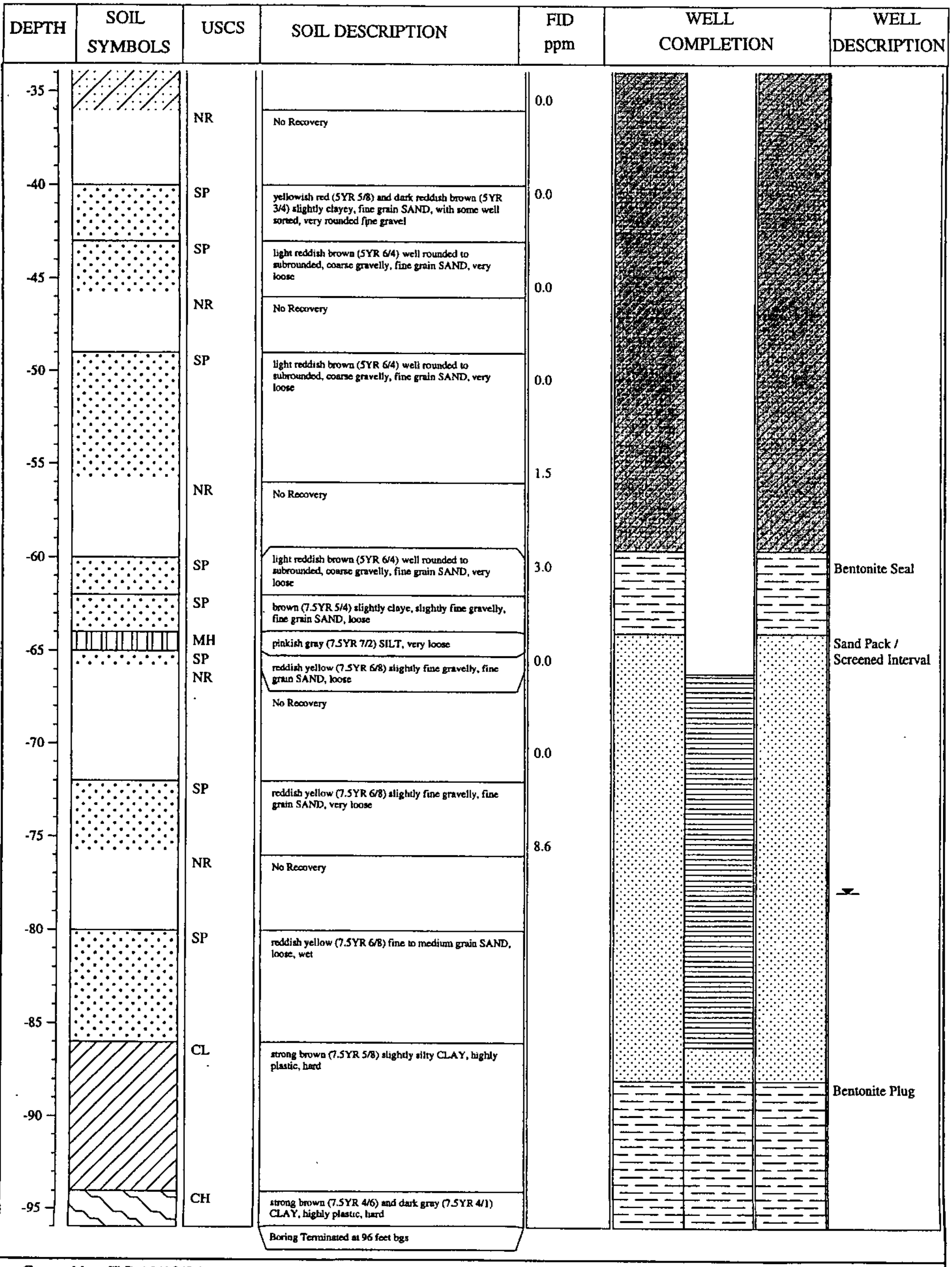




DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	FID ppm	WELL COMPLETION	WELL DESCRIPTION
0		Asphalt ML	asphalt, coarse grain SAND, loose and stiff brown (7.5YR 5/4) and brown (7.5 5/2) clayey SILT, soft			
-5		CL	brown (7.5YR 5/3) silty CLAY, medium stiff, medium plastic, moist	0.0		Grouted Annulus
-10				0.0		
-15		NR CL	No Recovery strong brown (7.5YR 5/8) silty CLAY, medium plastic, stiff	0.0		
-20				0.0		
-25		NR SC	No Recovery yellowish red (5YR 5/8) and reddish gray (5YR 5/2) clayey, fine grain SAND, slight fine gravel, stiff	0.0		
-30				0.0		

Created by: JLP 10/18/04
Checked by:

Borehole No. **MW-160**



USCS	SOIL DESCRIPTION
NR	No Recovery
SP	yellowish red (5YR 5/8) and dark reddish brown (5YR 3/4) slightly clayey, fine grain SAND, with some well sorted, very rounded fine gravel
SP	light reddish brown (5YR 6/4) well rounded to subrounded, coarse gravelly, fine grain SAND, very loose
NR	No Recovery
SP	light reddish brown (5YR 6/4) well rounded to subrounded, coarse gravelly, fine grain SAND, very loose
NR	No Recovery
SP	light reddish brown (5YR 6/4) well rounded to subrounded, coarse gravelly, fine grain SAND, very loose
SP	brown (7.5YR 5/4) slightly claye, slightly fine gravelly, fine grain SAND, loose
MH	pinkish gray (7.5YR 7/2) SILT, very loose
SP	reddish yellow (7.5YR 6/8) slightly fine gravelly, fine grain SAND, loose
NR	No Recovery
SP	reddish yellow (7.5YR 6/8) slightly fine gravelly, fine grain SAND, very loose
NR	No Recovery
SP	reddish yellow (7.5YR 6/8) fine to medium grain SAND, loose, wet
CL	strong brown (7.5YR 5/8) slightly silty CLAY, highly plastic, hard
CH	strong brown (7.5YR 4/6) and dark gray (7.5YR 4/1) CLAY, highly plastic, hard
	Boring Terminated at 96 feet bgs

Created by: JLP 10/18/04
Checked by:

APPENDIX D

HEALTH AND SAFETY PLAN ADDENDUM

HEALTH AND SAFETY PLAN ADDENDUM 1

Early Implementation of Selected Remedy – Dunn Field

Defense Logistics Agency
Defense Depot Memphis, Tennessee

MACTEC Engineering and Consulting, Inc.
3200 Town Point Drive, Suite 100
Kennesaw, Georgia 30144
MACTEC Project No. 6301-04-0019

Air Force Center for Environmental Excellence
Contract F41624-03-D-8606
Task Order No. 0069

October 2004

Early Implementation of Selected Remedy – Dunn Field
Health and Safety Plan Addendum
Defense Depot Memphis, Tennessee

I have read and understand the information set forth in this SSHP. I have also attended a pre-entry briefing. I agree to perform my work in accordance with this SSHP.

NAME	DATE	NAME	DATE

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LIST OF ATTACHMENTS

1.0 INTRODUCTION AND SITE OBJECTIVE

MACTEC Engineering and Consulting, Inc. (MACTEC) was retained by the United States Air Force Center for Environmental Excellence (AFCEE) under AFCEE Prime Contract F41624-03-D-8606 Task Order 69 to perform the work scope described in the Statement of Work (SOW) dated August 14, 2004 titled *Time Critical Interim Remedial Action at Dunn Field Defense Distribution Depot Memphis, Tennessee.*

This Health and Safety Plan Addendum is written to address field work associated with the injection of zero-valent iron (ZVI) to address groundwater contaminated with chlorinated volatile organic compounds (CVOCs) west of Dunn Field of the Defense Distribution Depot Memphis, Tennessee (DDMT). This Addendum should be used by MACTEC personnel only in tandem with the *Health and Safety Plan Main Installation and Dunn Field Defense Depot Memphis, Tennessee* prepared under Task Order No. 0038 in April 2004 (MACTEC, 2004), and not as a standalone health and safety plan.

ZVI consists of pure iron powder, which is specifically manufactured and packaged to prevent premature corrosion. Once released into the environment, oxidation of the iron under anaerobic conditions yields ferrous iron and hydrogen ions, both of which are reducing agents for chlorinated solvents. This ZVI injection is being conducted as an early implementation of a component of the selected groundwater remedy to address the highest concentrations of CVOCs at the leading edge of the plume.

2.0 FIELD WORK SUMMARY

The field work will consist of oversight activities associated with the drilling and installation of up to 18 temporary injection points in Area 1 and Area 2. ZVI will be pressure injected in discrete 2-foot intervals. The average treatment zone thickness in Area 1 will be 20 feet and in Area 2 will be 4 feet. Boreholes will be advanced by a rotosonic drill rig. The ZVI powder will be "food grade", mixed in discrete batches, and prepared at a concentration of 4 pounds per gallon of water.

The primary concern for personnel at the site is exposure to the primary constituents within the plume which are 1,1,2,2-tetrachloroethane (1,1,2,2-PCA), trichloroethene (TCE), and 1,2-dichloroethene (1,2-DCE). Concentrations of 1,1,2,2-PCA, TCE and 1,2-DCE are as high as 8000 µg/L, 3000 µg/L, and 74 µg/L, respectively (Attachment 1). Personnel may be exposed to these volatile constituents during drilling activities or during pressure injection operations at the site. In addition, working around fine grained iron particles (ZVI) has a potential for dust related concerns including both inhalation of dust and eye irritation.

A ZVI slurry will be blended into a pressurized nitrogen gas stream above ground and injected under pressure to the subsurface. The primary concerns in working with pressurized nitrogen are: (1) in the event of a release nitrogen gas may cause simple asphyxiation or; (2) in the event of a fire, severe overheating or material failure, the container or lines holding the pressurized nitrogen may rupture.

3.0 HAZARD ANALYSIS

The primary condition to avoid during the use of ZVI is the generation of airborne ZVI dust over a prolonged period of time which could cause fibrosis of the lungs. The OSHA permissible exposure level (PEL) for nuisance dust is 5 milligrams per cubic meter (mg/m^3). In addition, skin exposure to ZVI could cause a mild skin irritation. Material safety data sheets for ZVI Powder and Nitrogen Gas are included as Attachment 2. A ZVI slurry will be blended into a pressurized nitrogen gas stream aboveground and injected under pressure to the subsurface. The primary danger with working with pressurized nitrogen is that in the event of a release nitrogen gas may cause simple asphyxiation or in the event of a fire or severe overheating the container or lines holding the pressurized nitrogen may rupture. A job hazard analysis for the ZVI injection process is included in Attachment 3.

The remaining hazard analysis information per task including well installation is presented in Section 3 of the *Health and Safety Plan Main Installation and Dunn Field Defense Depot Memphis, Tennessee* (MACTEC, 2004).

4.0 AIR MONITORING

Environmental monitoring with a photoionization detector (PID) will be conducted during drilling and pressure injection activities for potential exposures to CVOCs. If a PID reading of 1 parts per million (ppm) or greater above background levels is maintained for 1 minute or more in the breathing zone, then detector tubes for 1,1,2,2-PCA will be utilized to determine if the air contaminant is 1,1,2,2-PCA and to measure its concentration (see Table 1). If peaks of 5 ppm or greater occur in the breathing zone, then a detector tube for chloroform will be utilized to determine if it is present and at what concentration. The air monitoring action guidelines presented in Table 1 are protective of airborne exposure from 1,2-dichloroethene and trichloroethene. Carbon tetrachloride has been eliminated from air monitoring due to the extremely low levels of detected concentrations for this chemical in the August 2004 groundwater monitoring.

TABLE 1
AIR MONITORING ACTION GUIDES

*** PID (ppm)**	**1,1,2,2-PCA** (ppm)**	**Chloroform (ppm)**	**Action**	**PPE**
< 1	--	--	Continue PID	Modified D
1 – 5	<0.1	--	Continue PID and Use DT	Modified D
5 – 25	<0.1	<5	Continue PID and Use DT	Modified D
5 – 25	>0.1 - <0.2	>5 – <50	Notify SHSO, Continue PID and Use DT	Level C
> 25	>0.2	> 50	Stop Work, Notify SHSO	

*Sustained 1 minute or more above background levels

**Perchloroethylene detector tube used for 1,1,2,2-PCA

DT - Detector Tubes

PCA (1,1,2,2) is present at Dunn Field at significant concentrations and was chosen as an indicator constituent because it has a low exposure threshold. A perchloroethylene (PCE) detector tube is used to detect 1,1,2,2-PCA in the field. A detection of 0.1 ppm on a PCE detector tube is approximately equal to 1 ppm of 1,1,2,2-PCA. In addition, a detection of 0.2 ppm on a PCE detector tube is approximately 5 to

10 ppm of 1,1,2,2-PCA. If the PCE detector tube readings are less than 0.1 ppm (and the PID reads from 1 to 5 ppm), then workers can remain in modified Level D PPE with periodic detector tube monitoring. If the PID reading is from 5 to 25 ppm OR the individual constituent detector tube readings exceed their unprotected thresholds (0.1 ppm for 1,1,2,2-PCA (PCE used) and 5 ppm for chloroform), then upgrade to Level C PPE, notify the SHSO or designee and continue periodic detector tube monitoring. If the detector tube reading is greater than 0.2 ppm for 1,1,2,2-PCA (PCE used) or 50 ppm for chloroform, work will be stopped until the SHSO can make further evaluations. At PID readings greater than 25 ppm, personnel will stop work immediately and notify the SHSO.

The AFCEE Technical Manager will be notified immediately if sustained PID readings of greater than 5 ppm are documented at the site. If PID breathing zone concentrations are maintained below 5 ppm, the frequency of PID monitoring may be reduced to 15-minute intervals. Air monitoring equipment, frequency of readings and action guidelines are summarized in Attachment 4. If respiratory protection is up-graded to full-face respirators or if evacuation occurs, the SHSO must notify MACTEC's RHSO.

At Dunn Field, SVOCs and metals are also present. Since, SVOCs and metals cannot be monitored with a PID, it is important to monitor dust levels in order to reduce the potential exposure to chemicals. In order to reduce the potential exposure to chemicals at or near Dunn Field, the dust levels at the site will be monitored visually. Dust suppression measures (i.e., water spray) will be utilized when there is visible dust in the air. Breathing zone conditions are not expected to reach sustained concentrations such that Level C PPE will be required. However, full-face respirators will be on-site if needed. Provisions for supplied air operations are not included in this SSHP, and workers will evacuate the Exclusion Zone if such conditions occur.

5.0 APPLICABLE UNCHANGED SECTIONS

The following listed sections are presented in the *Health and Safety Plan, Main Installation and Dunn Field, Defense Depot Memphis, Tennessee* (MACTEC, 2004) and remain appropriate and in force for this field effort.

- Key Personnel and Health and Safety Responsibilities
- Worker Training
- Medical Surveillance
- Site Control and Accident Prevention
- Cold/Heat Stress
- Personal Protective Equipment
- Decontamination
- Emergency Response
- Confined Space Entry
- Spill Containment
- Hazard Communication
- Record Keeping

6.0 REFERENCES

MACTEC, 2004. "Health and Safety Plan (Rev. 0). Main Installation and Dunn Field Defense Depot, Memphis, Tennessee," MACTEC Engineering and Consulting, Inc., April 2004.

ATTACHMENT 1

PRELIMINARY SUMMARY OF CVOCS DETECTED IN GROUNDWATER SAMPLES DUNN FIELD SOURCE AREA REMEDIAL DESIGN

Attachment 1

Preliminary Summary of CVOCs Detected in Groundwater Samples
Dunn Field Source Area Remedial Design

VOC Constituents	Well Number	MW-31	MW-32	MW-44	MW-54	MW-70	MW-76	MW-77	MW-79	MW-80	MW-144	MW-145	MW-147	MW-148	MW-149	MW-150	MW-151	MW-152	MW-153	MW-154	MW-155	MW-156	MW-157
	Sample ID	MW-31	MW-32	MW-44	MW-54	MW-70	MW-76	MW-77	MW-79	MW-80	MW-144	MW-145	MW-147	MW-148	MW-149	MW-150	MW-151	MW-152	MW-153	MW-154	MW-155	MW-156	MW-157
	Sample Depth (ft. BGS)	75	66.4	77.7	93	89.6	92.8	87.7	101.3	7.22	74.8	95.2	76.1	86.5	98.7	90.3	95.5	107.5	94	66	96	67.5	76
	Screen Interval (ft. BTOC)	64.1 - 79.1	52.7 - 67.7	64 - 74	84.5 - 94.5	80.8 - 90.8	73 - 93	68 - 88	82.5 - 102.5	53 - 73	56.1 - 76.1	80 - 100	57.6 - 77.6	67.1 - 87.1	79.6 - 99.6	70.6 - 90.6	77 - 97	89 - 109	76 - 96	52.8 - 67.8	75.6 - 95.6	49 - 69	57.2 - 77.2
	Date Sampled	12-Aug-04	13-Aug-04	14-Aug-04	14-Aug-04	14-Aug-04	16-Aug-04	15-Aug-04	13-Aug-04	17-Aug-04	12-Aug-04	16-Aug-04	17-Aug-04	17-Aug-04	18-Aug-04	18-Aug-04	16-Aug-04	15-Aug-04	19-Aug-04	17-Aug-04	16-Aug-04	20-Aug-04	18-Aug-04
Carbon Tetrachloride		<1.7	7.8	0.8 J	<100	<120	<2	<330	0.8 J	<1	<250	<1	4.3 J	0.7 J	12	<250	2.7	2.1 J	<1	<1	<77	<1	9.4
Chloroform		<1.7	68	0.4 J	<100	<120	0.5 J	<330	<1	<1	<250	<1	12	0.6 J	110	<250	3.3	0.97 J	<1	<1	<77	0.4 J	14
Chloromethane		<1.7	<2.5	<1	<100	<120	<2	<330	<1	<1	<250	<1	<5.6	<1	<5	<250	0.2 J	<3.3	<1	<1	<77	<1	<6.7
cis-1,2-Dichloroethene		<1.7	2.8	<1	65 J	<120	6.9	94 J	1.9	<1	68 J	<1	57	13	3.8 J	74 J	0.2 J	9.2	<1	<1	48 J	<1	11
trans-1,2-Dichloroethene		<1.7	<2.5	<1	<100	<120	3.5	<330	1.8	<1	<250	<1	20	4.9	<5	<250	<1	4.1	<1	<1	<77	<1	1.9 J
1,1-Dichloroethene		28	<2.5	<1	<100	<120	<2	<330	7.8	<1	<250	<1	2.2 J	<1	<5	<250	<1	<3.3	0.1	<1	<77	<1	<6.7
Methylene Chloride		<1.7	2.1 J	<1	<100	<120	<2	<330	<1	<1	<250	<1	<5.6	<1	2.5 J	130 J	<1	3.4	<1	<1	<77	<1	2.8 J
1,1,2,2-Tetrachloroethane		<1.7	21	<1	2300	3500	2.9	11000	<1	<1	7700	<1	56	0.7 J	27	8000	<1	11	<1	<1	2100	<1	5.7 J
Tetrachloroethene		0.6 J	0.97 J	<1	<100	<120	1.8 J	<330	1.7	<1	<250	<1	5.3 J	3.7	1.6 J	<250	<1	5.4	0.2 J	<1	<77	<1	1.9 J
Toluene		<1.7	<2.5	<1	<100	<120	<2	<330	<1	<1	<250	<1	<5.6	<1			<1	<3.3	4	<1	<77	<1	<6.7
1,1,1-Trichloroethane		0.4 J	<2.5	<1	<100	<120	<2	<330	0.3 J	<1	<250	<1	<5.6	<1	<5	<250	<1	<3.3	4	<1	<77	<1	<6.7
1,1,2-Trichloroethane		<1.7	<2.5	<1	<100	<120	<2	<330	<1	<1	<250	<1	<5.6	<1	<5	<250	<1	<3.3	<1	<1	<77	<1	<6.7
Trichloroethene		5.5	24	0.3 J	2200	970	34	3200	14	<1	2800	<1	120	31	38	3000	2.2	76	<1	<1	1000	<1	120

Notes
Monitoring Wells MW-151, -152, -153, -154, -155, -156 & -157 were installed/sampled in August 2004 and data is preliminary
J = estimated quantity between the Reporting Limit and the Method Detection Limit
BGS = below ground surface
BTOC = below top of casing
All units in µg/L and only COCs are presented in the table
▭ = detected concentration

ATTACHMENT 2

MATERIALS SAFETY DATA SHEETS FOR ZVI POWDER AND NITROGEN GAS

ARS Technologies Inc.

114 North Ward Street
New Brunswick, New Jersey
732.296.6620

Materials Safety Data Sheet

Section 1 - Identity:

H-200

Section 2 - Hazardous Ingredients:

MATERIAL (CAS REGISTRY NO.)	IRON (7439-89-6)
PERCENTAGE	97.0 +
OSHA PEL (TWA)	5 mg/m^3 as nuisance particulates

Section 3 - Physical/Chemical Data

Melting Point: 2798°F (1536°C)
Density: 7.8 g/cm^3
Appearance: Light to dark gray color. Fine powder. No odor.

Section 4 - Fire/Explosion Hazard Data:

Iron is not considered flammable under most conditions. Avoid airborne dispersion of any finely divided powder in an enclosed area to reduce potential for dust ignition.

Extinguish media: Dry chemical, sand, graphite to smother fire. Use water only in mist/fog application to avoid spreading powder/acclimated dust in surrounding areas.

Section 5-Reactivity Data:

Stability: Normally stable.
Conditions to avoid: Generation of airborne dust
Incompatibility (Materials to avoid): Pure oxygen or other strong oxidizers
Hazardous decomposition products: None
Hazardous polymerization: Will not occur

Section 6 - Health Hazard Data:

This material is not considered to be carcinogenic by IARC, NTP, or OSHA

Inhalation:	Prolonged overexposure to iron dusts may cause a chronic health condition of siderosis which is a benign pneumoconiosis with few or no symptoms.
Skin:	Exposure may cause mild irritation. Wash with soap and water. Seek medical attention if irritation persists.
Eyes:	Flush thoroughly with water for at least 15 minutes to avoid abrasive damage to outer surfaces of eye. Seek medical attention if irritation persists.
Ingestion:	Unlikely. Low oral toxicity. No acute or chronic health effects known.

Section 7 - Precautions for Safe Handling and use:

Keep in closed containers. Do not store near strong oxidizers. Use good housekeeping practices to prevent accumulation of dust. In the event of a spill, recommend use of a vacuum with a HEPA filter; use dust suppressant when sweeping. Avoid creation of any dust during cleanup. Reuse all spilled material whenever possible. Prevent spills from entering storm sewers or drains and contact with soil. Dispose of waste material at an appropriate waste disposal facility in accordance with current federal, state and local laws and regulations.

Section 8 - Control Measures:

Respiratory Protection: Use adequate ventilation to maintain airborne particulate levels below the recommended exposure limits. Use NIOSH-approved respirators in accordance with 29 CFR 1910.134 where levels exceed exposure limits.

Skin Protection: Use of a barrier cream and/or gloves by employees with skin sensitivity to this material is recommended.

Eye Protection: Wear safety glasses or goggles when handling this material to prevent eye contact. Do not wear contact lenses in any environment where dust or fumes are present. Readily available eye baths are recommended in areas where operations may produce dusts.

Section 9 - Regulatory Information

This product contains no chemicals reportable under the SARA 313 toxic release program.

Section 10 - Additional Information

Although reasonable care has been taken in the preparation of this document, we extend no warranties and make no representations as to accuracy or completeness of the information contained therein, and assume no responsibility regarding the suitability of this information for the user's intended purposes or for the consequences of its use. Each individual should make a determination as to the suitability of the information for his or her particular purpose(s).

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Material Safety Data Sheets

Division of Facilities Services

DOD Hazardous Material Information (ANSI Format) For Cornell University Convenience Only

NITROGEN GAS

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Cornell University does not in any way warrant or imply the applicability, viability or use of this information to any person or for use in any situation.

Section 1 - Product and Company Identification
NITROGEN GAS

Product Identification: NITROGEN GAS
Date of MSDS: 07/18/2000 **Technical Review Date:** 07/19/2000
FSC: 6830 **NIIN:** **LIIN:** NONE
Submitter: D DG
Status Code: A
MFN: 01
Article: N
Kit Part: N

Manufacturer's Information

Manufacturer's Name: BOUGHT ACCORDING TO SPECIFICATION
Post Office Box: .
Manufacturer's Address1: UNKNOWN
Manufacturer's Address2: UNKNOWN, NK 00000
Manufacturer's Country: NK
General Information Telephone: UNKNOWN
Emergency Telephone: 800-851-8061
Emergency Telephone: 800-851-8061
MSDS Preparer's Name: UNKNOWN
Proprietary: N
Reviewed: Y
Published: Y
CAGE: 81349
Special Project Code: N

Contractor Information

Contractor's Name: MILITARY SPECIFICATIONS PROMULGATED BY MILITARY
Post Office Box: MANUAL
Contractor's Address1: DEPTS/AGENCIES UNDER AUTH OF DEF STD
Contractor's Address2: 4120 3-M, NK 00000
Contractor's Telephone: 804-279-4371 DSN 695-4371
Contractor's CAGE: 81349

Section 2 - Compositon/Information on Ingredients
NITROGEN GAS

Ingredient Name: NITROGEN
Ingredient CAS Number: 7727-37-9 **Ingredient CAS Code:** M
RTECS Number: QW9700000 **RTECS Code:** M
=WT: =WT Code:
=Volume: =Volume Code:
>WT: 99.5 **>WT Code:** M
>Volume: >Volume Code:
<WT: <WT Code:
<Volume: <Volume Code:
% Low WT: % Low WT Code:
% High WT: % High WT Code:
% Low Volume: % Low Volume Code:
% High Volume: % High Volume Code:
% Text:
% Enviromental Weight:
Other REC Limits: NONE RECOMMENDED
OSHA PEL: NOT ESTABLISHED **OSHA PEL Code:** M
OSHA STEL: N/P **OSHA STEL Code:**
ACGIH TLV: ASPHYXIANT; 9596 **ACGIH TLV Code:** M
ACGIH STEL: N/P **ACGIH STEL Code:**
EPA Reporting Quantity:
DOT Reporting Quantity:

Ozone Depleting Chemical: N

Section 3 - Hazards Identification, Including Emergency Overview
NITROGEN GAS

Health Hazards Acute & Chronic: TARGET ORGANS: RESPIRATORY SYSTEM, CENTRAL NERVOUS SYSTEM. ACUTE- NITROGEN IS NONTOXIC BUT CAN PRODUCE SUFFOCATION BY DISPLACING OXYGEN. PROLONGED INHALATION OF HIGH CONCENTRATIONS CAN CAUSE UNCONSCI OUSNESS, CONVULSIONS, POSSIBLE DEATH. THIS PRODUCT IS A GAS. CANNOT BE SWALLOWED OR CONTACTED. CHRONIC- NONE.

Signs & Symptoms of Overexposure:
DIZZINESS, TIGHTNESS IN FRONTAL AREA OF FOREHEAD, TINGLING OF TONGUE, FINGERTIPS OR TOES, WEAKENED SPEECH LEADING TO INABILITY TO UTTER SOUNDS; RAPID REDUCTION IN ABILITY TO PERFORM MOVEMENTS, REDUCED CONSCIOUSNESS OF SURROUNDINGS, RINGINGIN EARS, HEADACHE, NAUSEA, VOMITING, BLUE SKIN COLOR, UNCONSCIOUSNESS, DEATH

Medical Conditions Aggravated by Exposure:
UNKNOWN

LD50 LC50 Mixture: NOT RELEVANT

Route of Entry Indicators:
- **Inhalation:** YES
- **Skin:** NO
- **Ingestion:** NO

Carcenogenicity Indicators
- **NTP:** NO
- **IARC:** NO
- **OSHA:** NO

Carcinogenicity Explanation: NONE

Section 4 - First Aid Measures
NITROGEN GAS

First Aid:
PROMPT MEDICAL ATTENTION IS MANDATORY IN ALL CASES OF OVEREXPOSURE. RESCUE PERSONNEL SHOULD WEAR SELF-CONTAINED BREATHING APPARATUS. INHALED: REMOVE TO FRESH AIR. PROVIDE OXYGEN/CPR IF NEEDED. EYE/ SK IN/ORAL:UNLIKELY (GAS)

Section 5 - Fire Fighting Measures
NITROGEN GAS

Fire Fighting Procedures:
AS WITH ANY FIRE, WEAR PROTECTIVE CLOTHING AND NIOSH-APPROVED SELF-CONTAINED BREATHING APPARATUS IF NEEDED.

Unusual Fire or Explosion Hazard:
CONTAINER MAY RUPTURE.
Extinguishing Media:
USE WATER FOG, CARBON DIOXIDE, FOAM, OR DRY CHEMICAL FOR SURROUNDING FIRE. KEEP FIRE-EXPOSED CYLINDERS COOL WITH WATER.
Flash Point: Flash Point Text: NONE

Autoignition Temperature:
Autoignition Temperature Text: N/R
Lower Limit(s): NOT RELEVANT
Upper Limit(s): NOT RELEVANT

Section 6 - Accidental Release Measures
NITROGEN GAS

Spill Release Procedures:
EVACUATE ALL PERSONNEL FROM AFFECTED AREA. USE APPROPRIATE PROTECTIVE EQUIPMENT. VENTILATE AREA. IF LEAK IS FROM CYLINDER OR ITS VALVE, CONTACT YOUR SUPPLIER. THE ATMOSPHERE MUST HAVE AT LEAST 19.5% O XYGEN BEFORE PERSONNEL CAN BE ALLOWED IN THE AREA.

Section 7 - Handling and Storage
NITROGEN GAS

Handling and Storage Precautions:

Other Precautions:

Section 8 - Exposure Controls & Personal Protection
NITROGEN GAS

Repiratory Protection:
IF OXYGEN LEVEL IS BELOW 19.5%, USE NIOSH-APPROVED SELF-CONTAINED BREATHING APPARATUS OR SUPPLIED AIR RESPIRATOR, OPERATED IN POSITIVE PRESSURE MODE.
Ventilation:
GENERAL
Protective Gloves:
LEATHER WHEN HANDLING CYLINDERS
Eye Protection: GOGGLES/GLASSES RECOMMENDED
Other Protective Equipment: SAFETY SHOES WHEN HANDLING CYLINDERS
Work Hygenic Practices: OBSERVE GOOD INDUSTRIAL HYGIENE PRACTICES AND RECOMMENDED PROCEDURES.
Supplemental Health & Safety Information: N/P

Section 9 - Physical & Chemical Properties
NITROGEN GAS

HCC: G3
NRC/State License Number: NOT RELEVANT

Net Property Weight for Ammo: N/R
Boiling Point: Boiling Point Text: -320F,-196C
Melting/Freezing Point: Melting/Freezing Text: -346F,-210C
Decomposition Point: Decomposition Text: N/R
Vapor Pressure: UNKNOWN **Vapor Density:** 0.967
Percent Volatile Organic Content:
Specific Gravity: NOT RELEVANT
Volatile Organic Content Pounds per Gallon:
pH: N/R
Volatile Organic Content Grams per Liter:
Viscosity: NOT RELEVANT
Evaporation Weight and Reference: NOT RELEVANT (GAS)
Solubility in Water: SLIGHT
Appearance and Odor: COLORLESS, ODORLESS GAS
Percent Volatiles by Volume: 100
Corrosion Rate: N/R

Section 10 - Stability & Reactivity Data
NITROGEN GAS

Stability Indicator: YES
Materials to Avoid:
TITANIUM (WILL BURN IN NITROGEN), LITHIUM (SLOWLY REACTS)
Stability Condition to Avoid:
HEATING CYLINDER
Hazardous Decomposition Products:
NONE
Hazardous Polymerization Indicator: NO
Conditions to Avoid Polymerization:
NOT RELEVANT

Section 11 - Toxicological Information
NITROGEN GAS

Toxicological Information:
N/P

Section 12 - Ecological Information
NITROGEN GAS

Ecological Information:
N/P

Section 13 - Disposal Considerations
NITROGEN GAS

Waste Disposal Methods:
DISPOSE OF IN ACCORDANCE WITH LOCAL, STATE AND FEDERAL REGULATIONS. RETURN IN THE SHIPPING CONTAINER PROPERLY LABELED, WITH ANY VALVE OR CAPS SECURED TO YOUR SUPPLIER FOR PROPER DISPOSAL.

Section 14 - MSDS Transport Information

NITROGEN GAS

Transport Information:
PSN: NITROGEN, COMPRESSED, 2.2, UN1066. LABEL: NON-FLAMMABLE GAS.

Section 15 - Regulatory Information
NITROGEN GAS

SARA Title III Information:
N/P
Federal Regulatory Information:
N/P
State Regulatory Information:
N/P

Section 16 - Other Information
NITROGEN GAS

Other Information:
N/P

HMIS Transportation Information

Product Identification: NITROGEN GAS
Transporation ID Number: 154103
Responsible Party CAGE: 81349
Date MSDS Prepared: 07/18/2000
Date MSDS Reviewed: 07/19/2000
MFN: 07/19/2000
Submitter: D DG
Status Code: A

Container Information
- **Unit of Issue:** NK
- **Container Quantity:** NK
- **Type of Container:**
- **Net Unit Weight:**

Article without MSDS: N
Technical Entry NOS Shipping Number:
Radioactivity:
Form:
Net Explosive Weight: N/A
Coast Guard Ammunition Code:
Magnetism: N/A
AF MMAC Code:
DOD Exemption Number: N/A
Limited Quantity Indicator: N
Multiple Kit Number: 0
Kit Indicator: N
Kit Part Indicator: N
Review Indicator: N
Additional Data:

Department of Transportation Information

DOT Proper Shipping Name: NITROGEN, COMPRESSED
DOT PSN Code: KLZ
Symbols:
DOT PSN Modifier:
Hazard Class: 2.2
UN ID Number: UN1066
DOT Packaging Group:
Label: NONFLAMMABLE GAS
Special Provision(s):
Packaging Exception: 306
Non Bulk Packaging: 302
Bulk Packaging: 314,315
Maximimum Quanity in Passenger Area: 75 KG
Maximimum Quanity in Cargo Area: 150 KG
Stow in Vessel Requirements: A
Requirements Water/Sp/Other:

IMO Detail Information

IMO Proper Shipping Name: NITROGEN, COMPRESSED
IMO PSN Code: KSR
IMO PSN Modifier:
IMDG Page Number: 2163
UN Number: 1066
UN Hazard Class: 2(2.2)
IMO Packaging Group: -
Subsidiary Risk Label: -
EMS Number: 2-04
Medical First Aid Guide Number: NON

IATA Detail Information

IATA Proper Shipping Name: NITROGEN, COMPRESSED
IATA PSN Code: SBP
IATA PSN Modifier:
IATA UN Id Number: 1066
IATA UN Class: 2.2
Subsidiary Risk Class:
UN Packaging Group:
IATA Label: NON-FLAMMABLE GAS
Packaging Note for Passengers: 200
Maximum Quantity for Passengers: 75KG
Packaging Note for Cargo: 200
Maximum Quantity for Cargo: 150KG
Exceptions:

AFI Detail Information

AFI Proper Shipping Name: NITROGEN, COMPRESSED
AFI Symbols:
AFI PSN Code: SBP
AFI PSN Modifier:
AFI UN Id Number: UN1066
AFI Hazard Class: 2.2

AFI Packing Group: N/A
AFI Label:
Special Provisions: P5
Back Pack Reference: A6.3, A6.6

HAZCOM Label Information

Product Identification: NITROGEN GAS
CAGE: 81349
Assigned Individual: N
Company Name: MILITARY SPECIFICATIONS PROMULGATED BY MILITARY
Company PO Box: MANUAL
Company Street Address1: DEPTS/AGENCIES UNDER AUTH OF DEF STD
Company Street Address2: 4120 3-M, NK 00000 NK
Health Emergency Telephone: 800-851-8061
Label Required Indicator: Y
Date Label Reviewed: 07/19/2000
Status Code: A
Manufacturer's Label Number:
Date of Label:
Year Procured: N/K
Organization Code: F
Chronic Hazard Indicator: N/P
Eye Protection Indicator: N/P
Skin Protection Indicator: N/P
Respiratory Protection Indicator: YES
Signal Word: CAUTION
Health Hazard: Slight
Contact Hazard: None
Fire Hazard: None
Reactivity Hazard: None

8/9/2002 10:46:19 AM

ATTACHMENT 3

JOB HAZARD ANALYSIS FOR ZVI INJECTION

ATTACHMENT 3

<table>
<tr><td rowspan="3">SPECIFIC SAFE WORK PRACTICES
JOB SAFETY ANALYSIS
ZVI Injection</td><td rowspan="2">Name of Job:
Defense Depot
Memphis, Tennessee</td><td rowspan="2">JSA No.
______</td><td rowspan="2">Page <u>01</u> of <u>02</u></td><td rowspan="2">Date:
10/12/04</td><td>X</td><td>New</td></tr>
<tr><td></td><td>Revised</td></tr>
<tr><td>Title of person who does job:
Field Geologist/Site Safety Supervisor</td><td colspan="2">Supervisor:
Bill Payne</td><td colspan="3">Analysis by:
Emmet Curtis</td></tr>
<tr><td>Company/Organization:
MACTEC, Inc.</td><td>Plant/Location:
Memphis, TN</td><td colspan="2">Department:
DDMT Field Team</td><td colspan="3">Reviewed by:
David Price</td></tr>
<tr><td colspan="4">Required and/or recommended
Personal Protective Equipment: Hard hat, steel-toe boots, safety glasses, hearing protection, tyvek</td><td colspan="3">Approved by:
David Price</td></tr>
</table>

Sequence and Description of Basic Job Steps	Potential Hazards	Recommended Action or Procedure
1). Travel to and from job site	1). Vehicle accident	1). Drivers complete MACTEC Driving Safety Training; comply with MACTEC vehicle operation guidelines
2). Set-up traffic control to alert the traveling public when working in or near the Right-of-Way	2). Struck by moving vehicle	2). Wear traffic safety vest to increase visibility and be alert to oncoming street/highway traffic
3). Off-load drilling equipment, tools and supplies	3A). Struck by moving vehicle	3A). Maintain eye contact with driver of drill rig and be alert to oncoming street/highway traffic
	3B). Back injuries	3B). Utilize proper lifting techniques
4). Hazard communication and recognition	4). Overhead and underground utilities: electrical, gas, communications, water, etc.	4). Identify utility locations prior to mobilizing; interview property owners and/or employ a private utility locator; drill at adequate offsets from utility locations; identify area medical facilities, emergency travel routes and phone numbers
5). Moving equipment on site	5). Struck by moving vehicle	5). Utilize signs/flags to control street/highway traffic during road crossings; use heavy equipment back up alarms on drill rig

ATTACHMENT 3

SPECIFIC SAFE WORK PRACTICES JOB SAFETY ANALYSIS **Drilling/Monitoring Well Installation/Abandonment**		**Page 02 of 02**
6). General drilling duties at the job site	6A). Struck by debris or equipment; slips, trips and potential falls	6A). Proper training of personnel; use of proper personal protection equipment (Hard hats, steel toe boots, safety glasses, gloves, etc.); maintain site housekeeping on drill rig
	6B). Back injuries	6B). Utilize proper lifting techniques
	6C). Weather extremes: heat, cold, rain and lightning	6C). Wear appropriate clothing; consume fluids, take necessary breaks; awareness of the potential for lightning; wait out hazardous situations
	6D). Outdoor safety: biological hazards	6D). Watch-where-you-step; wear protective clothing
	6E). Exposure to chemicals of concern	6E). Wear appropriate personal protective equipment and monitor breathing air with a photoionization detector.
7). Pneumatic Fracturing/ZVI Injection	7A). Struck by broken pressure line	7A). Wear appropriate personal protection equipment and examine pressure.
	7B). Exposure to ZVI dust	7B). Wear nitrile gloves when working with powder and do not agitate powder to generate a dust
	7C). Exposure to nitrogen gas	7C). Move to an oxygen sufficient location upwind of release
	7D). Struck by moving equipment	7D). Maintain driver of moving vehicle in sight at all times and use heavy equipment backup alarms.
	7E). Exposure to chemicals of concern	7E). Wear appropriate personal protective equipment and monitor breathing air with a photoionization detector.
Date of field verification and validation:	**Names of personnel that completed field verification and validation:**	

ATTACHMENT 4

AIR MONITORING EQUIPMENT, FREQUENCY OF READINGS, AND ACTION GUIDELINES PER TASK(S)

ATTACHMENT 4

AIR MONITORING EQUIPMENT/FREQUENCY OF READINGS/ACTION GUIDELINES

TASK(S): All Activities Scheduled for DDMT

x * Explosimeter **Brand/Model No. Neotronics** **Monitoring Frequency: Continuously (for intrusive drilling activities only)**		**x * Oxygen Meter** **Brand/Model No. Neotronics** **Monitoring Frequency: Continuously (for intrusive drilling activities only)**		**X *Photoionization Detector** **Brand/Model No.: Micro tip** **Monitoring Frequency: Continuously**	
Source Reading (% LEL)	Action	Source Reading (%)	Action	Breathing Zone Reading (ppm)	Action
1 to 10	Continue with caution	<19.5	Stop work. Evacuate the area.	0 to 1	Modified Level D PPE
≥10	Stop work. Evacuate area. If action levels continue to be exceeded, contact HSO.	19.5 to 23.5	Continue to work with caution	≥1 to ≤5	Check with detector tubes (See DT below)
		≥23.5	Stop work. Evacuate the area.	≥5 to ≤25	Use Level C PPE and check with detector tubes (See DT below)
				Note: >25 ppm stop work, notify SHSO prior to continuing work.	
X * Chemical Detector Tube **Brand/Model No.: Drager (chloroform)** **Monitoring Frequency: Every positive detection on PID (1 ppm above background sustained for 1 minute)**		**X * Chemical Detector Tube** **Brand/Model No.: Drager (1,1,2,2-Tetrachloroethane)** **Monitoring Frequency: Every positive detection on PID (1 ppm above background sustained for 1 minute)**			
Breathing Zone Reading (ppm)	Action	Breathing Zone Reading (ppm)	Action		
0 to ≤5	Modified Level D PPE	0 to ≤1	Modified Level D PPE		
5 to ≤50	Level C and notify SHSO	1 to <5	Level C PPE and notify SHSO		
Note: > 50 ppm stop work, notify SHSO.		Note: > 5 ppm stop work, notify SHSO.			

* Mark equipment required for this task with "X"

FINAL PAGE

ADMINISTRATIVE RECORD

FINAL PAGE